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Acronyms

1,2-DCB	1,2-dichlorobenzene
1,2-DCE	1,2-dichloroethene
1,3-DCB	1,3-dichlorobenzene
1,4-DCB	1,4-dichlorobenzene
1,4-DCE	1,4-dichloroethene
ACL	alternate concentration limits
AOC	area of concern
AFB	air force base
AFCEE	Air Force Center for Environmental Excellence
APU	alternate power unit
ARARs	applicable or relevant and appropriate requirements
AST	above-ground storage tanks
AVGAS	aviation gasoline
bgs	below ground surface
BRA	Basewide Remedial Assessment
BTEX	benzene, toluene, ethylbenzene, and xylene
CAA	*Clean Air Act*
CB	chlorobenzene
CFR	*Code of Federal Regulations*
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act*
CMS	Corrective Measures Study
COC	contaminant of concern
COPC	contaminant of potential concern
CVOC	chlorinated volatile organic compound
cy	cubic yards
DCE	dichloroethene
DERP	Defense Environmental Restoration Program
DoD	Department of Defense
DDT	dichlorodiphenyltrichloroethane
EPA	U.S. Environmental Protection Agency
EPCF	Environmental Process Control Facility
EPS	effluent polishing system
FFS	focused feasibility study
FS	feasibility study
F_{oc}	Fraction of organic carbon
GAC	granular activated carbon
GCL	geosynthetic clay liner
gpd	gallons per day
gpm	gallons per minute
GRA	general response action
GWP	groundwater protection
GWTP	Groundwater Treatment Plant

1	HDPE	high density polyethylene
2	HI	hazard index
3	HRC	hydrogen release compound
4	IWTP	industrial waste treatment plant
5	IRP	installation restoration program
6	K_d	distribution coefficient
7	K_{oc}	organic carbon partition coefficient
8	LNAPL	liquid nonaqueous phase liquid
9	MCL	maximum contaminant levels
10	mgd	million gallons per day
11	mg/kg	milligrams per kilograms
12	MSC	Media-Specific Concentration
13	MW	Mini-wells
14	NB	North Bank
15	NCP	National Contingency Plan
16	NEPA	*National Environmental Policy Act*
17	NPL	National Priorities List
18	NPDES	National Pollutant Discharge Elimination System
19	O&M	operation and maintenance
20	ORC	Oxygen Release Compound
21	PCB	polychlorinated biphenyls
22	PCE	tetrachloroethene
23	PES	Parsons Engineering Science
24	POTW	publicly-owned treatment works
25	PRG	preliminary remediation goal
26	PST	petroleum storage tank
27	PVC	polyvinyl chloride
28	R	retardation coefficient
29	RAO	remedial action objective
30	RCRA	*Resource Conservation and Recovery Act of 1976*
31	RF	radio frequency
32	RI	remedial investigation
33	RRS	risk reduction standard
34	SA-ALC	San Antonio Air Logistics Center
35	SAIC	Science Applications International Corporation
36	SAWS	San Antonio Water System
37	scfm	standard cubic feet per minute
38	SDWA	*Safe Drinking Water Act*
39	SPLP	Synthetic Precipitation Leaching Procedure
40	SVE	soil vapor extraction
41	SVOC	semivolatile organic compound
42	SWL	Southwestern Laboratories
43	SWMU	solid waste management unit
44	TAC	*Texas Administrative Code*
45	TBC	to be considered
46	TCE	trichloroethene
47	TCLP	toxicity characteristic leach procedure

1	TMV	toxicity, mobility, or volume
2	TNRCC	Texas Natural Resource Conservation Commission
3	TOC	total organic carbon
4	TPH	total petroleum hydrocarbons
5	USAF	U.S. Air Force
6	USACE	U.S. Army Corps of Engineers
7	USEPA	U.S. Environmental Protection Act
8	UV	ultraviolet
9	VC	vinyl chloride
10	VOC	volatile organic compound
11	WMA	waste management area

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Executive Summary

Introduction

The purpose of this Corrective Measures Study (CMS) is to evaluate final remedial alternatives for on-base and off-base shallow groundwater contamination in Zone 5 at Kelly Air Force Base (AFB) in San Antonio, Texas. This CMS integrates the findings of previous reports addressing interim remedial actions for shallow groundwater in Zone 5 with an evaluation of remedial alternatives for other Zone 5 areas of concern that have not been previously evaluated. Thus, this document concludes the remedy selection portion of the phased approach to remediation of Zone 5. It is anticipated that an alternative, or combination of alternatives, will be selected from this CMS report by AFBCA/DK and the regulatory agencies and presented in a separate proposed plan to the public for review and comment.

Background

Former Kelly AFB consists of two non-contiguous areas, the main portion of former Kelly AFB and East Kelly. As a result of past waste management practices, the shallow groundwater underlying and adjacent to the installation have become contaminated. To organize cleanup at the installation, former Kelly AFB is divided into five zones. Zone 5 consists of all on base areas outside of Zones 1 through 4. This CMS report is focused on evaluation of remedial alternatives at and immediately adjacent to Zone 5.

Former Kelly AFB is authorized for closure and post-closure care of certain hazardous waste units under Permit No. HW-50310 issued by the Texas Natural Resource Conservation Commission (TNRCC). The permit and associated compliance plan specify cleanup requirements for solid waste management units, including many in Zone 5. The cleanup of former Kelly AFB is also being addressed pursuant to the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) and the Department of Defense Environmental Restoration Program (DERP). The USAF program is called the Installation Restoration Program (IRP) and it is conducted in a manner that is consistent with both CERCLA and the National Contingency Plan, even for those USAF installations that are not on the U.S. Environmental Protection Agency's National Priorities List. Kelly AFB is one of the installations being addressed under the IRP; it is not, however, on the National Priorities List.

Soil Characterization

Contaminants of concern (COCs) for soil in Zone 5 are present only at site SS003 (S-1). They consist of CB and its co-contaminants, 1,2-DCB and 1,4-DCB, TCE, PCE, benzene, and PCBs. The principal Zone 4 source site is SS003 (S-1). An interim action consisting of removal and disposal of contaminated soil at the former sump area and SVE in conjunction with

groundwater recovery and treatment at the "smear zone" was implemented in June 2001. This interim action represents the final action at Site S-1. Therefore, no other soil evaluation is needed in this CMS.

Groundwater Characterization

The 1999 Final Zone 5 Remedial Investigation (RI) Report constitutes the primary source of environmental data used for this CMS. The RI data have been supplemented by several more recent supplementary characterization efforts.

Groundwater Contamination

A total of 35 contaminants of potential concern were identified in Zone 5 groundwater, resulting in the delineation of eleven distinct groundwater contaminant plumes designated A through K (not including Plumes C, E, G, and I, which will be covered in separate reports). The plumes were grouped by location of contamination, and, for some constituents, the similarity between chemistry. The key contaminants of potential concern in groundwater include trichloroethene (TCE), dichloroethene (DCE), 1,2-DCE, tetrachloroethene (PCE), benzene, Chlorobenzene (CB), and arsenic. As shown in Figure ES.1, the groundwater contaminant plumes and the key contaminants of potential concern present in each are as follows:

- Plume A (TCE)
- Plume B (PCE)
- Plume D (TCE, PCE, and 1,2-DCE)
- Plume F (PCE/TCE)
- Plume H (TCE and total 1,2-DCE)
- Plume J (PCE and TCE)
- Plume K (CB).

The source area[1] and the body of Plume B are located offbase and the plume is migrating to the north/northeast, away from Kelly AFB. The plume is not within Zone 5 and is not related to operations at Kelly AFB. However, even though the plume is not related to Kelly AFB activities, remedial alternatives are evaluated in Section 9.0..

Remedial Action Objectives

The shallow groundwater both on-base and off-base poses unacceptable risks. It is unlikely that on base groundwater will ever be withdrawn directly for use as a drinking water supply, but it still poses risks because it is migrating off-base. Based on this, the following are objectives for groundwater remedial actions for Zone 5:

[1] "Source area" is used throughout this report to indicate an area in the contamination plume in which the groundwater exhibits high contaminant concentrations relative to the rest of the plume. "Source area" is the area within which the source of groundwater contamination probably originated in the past. Unless otherwise indicated, "source area" does not mean that there is presently an active source of contamination.

1. Prevent use of both on-base and off-base groundwater containing contaminants in concentrations exceeding MCLs, or where those are not available, Texas groundwater medium-specific concentrations.

2. Reduce or prevent further migration of contaminated groundwater (defined as groundwater with contaminant concentrations that exceed MCLs or, where those are not available, Texas groundwater medium-specific concentrations) from on-base areas to off-base areas. [2]

3. Restore off-base groundwater to MCLs or, where those are not available, to Texas groundwater medium-specific concentrations, within a reasonable time frame.

4. Restore on-base groundwater to MCLs or, where those are not available, to Texas groundwater medium-specific concentrations, within a reasonable time frame. If that time frame exceeds 20 years, establish alternate concentration limits (ACLs) that are no greater than existing contaminant concentrations and ensure that those ACLs are met during the interim time period.

Preliminary Remediation Goals

Preliminary remediation goals (PRGs) were developed for groundwater to establish acceptable concentrations for each COC under relevant exposure settings. PRGs for groundwater COCs were developed from the 30 TAC 335.568, Appendix II Table of medium-specific concentrations and the TNRCC Compliance Plan for Kelly AFB. For each contaminant, the more stringent value of the two sources constitutes the PRG used in this CMS for identifying the extent of groundwater to be remediated.

Development of Remedial Action Alternatives

General response actions (GRAs) were selected to satisfy the remedial action objectives and PRGs by either reducing concentrations of hazardous substances or by reducing the likelihood of contact with hazardous substances. They include actions such as treatment, containment, collection, disposal, and institutional controls. Although one response action may meet the goals, a combination of response actions may meet the goals more effectively.

The technology types and process options available for remediation of groundwater were identified and screened for suitability to eliminate those technologies that are clearly not applicable for remediation. Technology types and process options considered are based on professional experience, published sources, computer databases, and other available documentation for the identified GRAs. GRA's that remained following screening were developed into remedial action alternatives.

Remedial Alternatives for Groundwater

Nine remedial alternatives were developed for groundwater contaminant plumes:

[2] For purposes of selecting an appropriate remedial action, the term "on base" refers only to those areas of Kelly AFB that are be maintained under federal control following base closure. The term "off base" refers both to those areas that are currently outside the Kelly AFB boundaries and to those areas that were transferred to a non-federal entity following base closure.

- Alternative 1 - No Further Action
- Alternative 2 - Monitored Natural Attenuation
- Alternative 3 - Source Control
- Alternative 4 - Source Ex Situ and In Situ Treatment, Perimeter Control and Off Base Control
- Alternative 5 - Source and Perimeter Control
- Alternative 6 - Targeted Source and Perimeter Control
- Alternative 7 - Source Ex Situ and In Situ Treatment and Perimeter Control
- Alternative 8 – In situ Oxygen Treatment for Plume A Source and In Situ Perimeter Control
- Alternative 9 – In Situ Bioremediation Treatment for Plume A and In Situ Perimeter Control

Detailed and Comparative Analyses of Alternatives

The detailed analysis of alternatives presents the relevant information needed to compare the remedial alternatives assembled for groundwater contaminant plumes. Provisions of the National Contingency Plan require that each alternative be evaluated against nine criteria listed in 40 CFR 300.430(e)(9), as follows:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- Community acceptance
- State acceptance

State and community acceptance will be assessed at the conclusion of the public comment period. In addition, because this document also serves to satisfy the Kelly AFB obligations under NEPA, the detailed analysis considers potential environmental impacts that are not otherwise addressed by CERCLA criteria. The results of the detailed analyses for each individual alternative are used to provide a basis for comparison of the relative performance of each of the alternatives and to identify their relative advantages and disadvantages. This approach is intended to provide sufficient information to adequately compare the alternatives and to allow Kelly AFB, the regulatory agencies, and the public to eventually

select the most appropriate alternative or combination of alternatives for implementation at the site as remedial actions.

Comparative Evaluation for Groundwater Remediation Alternatives

Overall Protection of Human Health and Environment

Except for the No Further Action Alternative, all of the alternatives are protective of human health and the environment and prevent the use of contaminated groundwater by using administrative controls to restrict the use of the on base shallow groundwater.

Except for the No Further Action Alternative, all of the alternatives substantially reduce or eliminate further migration of contaminants through the groundwater by intercepting or eliminating contaminants in the groundwater at various locations both on and off base.

The Source Ex Situ and In Situ Treatment, Perimeter Control and Off Base Control, Source and Perimeter Control, Targeted Source and Perimeter Control, and Source Ex Situ and In Situ Treatment and Perimeter Control Alternatives (Alternatives 4 through 9) would restore the groundwater contaminant levels in this region in about 21 years. The No Further Action and Monitored Natural Attenuation Alternatives would require about 30 years to achieve this result.

In areas subject to base closure (essentially the area east of the runway), the Source Control, Source Ex Situ and In Situ Treatment, Perimeter Control and Off Base Control, Source and Perimeter Control, Targeted Source and Perimeter Control, and Source Ex Situ and In Situ Treatment and Perimeter Control Alternatives (Alternatives 3 through 9) would restore groundwater contaminant concentrations to PRGs in the least amount of time (25 to 30 years) while the No Further Action and Monitored Natural Attenuation Alternatives would achieve this objective over the longest time frame (28 years or more).

In areas that will remain under Department of Defense control, Source Ex Situ and In Situ Treatment, Perimeter Control and Off Base Control, Source and Perimeter Control, and Source Ex Situ and In Situ Treatment and Perimeter Control Alternatives (Alternatives 3, 4, 5, and 7) would reduce contamination levels to PRGs in about 25 to 30 years. The No Further Action, Monitored Natural Attenuation, and Targeted Source and Perimeter Control Alternatives (Alternatives 1, 2, and 6) would take 14 to 28 years to achieve this result.

Source control and upgrade of the existing perimeter pump and treat systems as necessary (Source Control, Source and Perimeter Control, and Source Ex Situ and In Situ Treatment and Perimeter Control Alternatives [Alternatives 3, 5, and 7]) would be effective at reducing off base contaminant levels in a reasonable time frame (remedial action objectives 4 and 5). Of those alternatives, only the Source and Perimeter Control and Source Ex Situ and In Situ Treatment and Perimeter Control Alternatives would be effective at reducing on base contaminant levels (remedial action objective number 4).

Compliance with ARARs

Except for the No Further Action Alternative, all alternatives would comply with ARARs by meeting National Pollution Discharge Elimination System permit discharge limits. Air emissions (if any) would meet concentration and volume limits for discharge of VOCs under the state standard exemption for remediation.

Long-Term Effectiveness

All alternatives would be effective in the long term, although each alternative would vary in the time frame needed to meet the objectives. The active remediation alternatives (Source Control, Source Ex Situ and In Situ Treatment, Perimeter Control and Off Base Control, Source and Perimeter Control, Targeted Source and Perimeter Control, and Source Ex Situ and In Situ Treatment and Perimeter Control Alternatives [Alternatives 3 through 9]) achieve the PRGs in shorter time than the passive remediation alternatives (No Further Action and Monitored Natural Attenuation [Alternatives 1 and 2]).

All of the alternatives, including the passive remediation alternatives) involve remediation mechanisms that are generally irreversible. There is no residual risk once the concentrations have been reduced to acceptable levels.

Reduction of Toxicity, Mobility, or Volume Through Treatment

The No Further Action and Monitored Natural Attenuation Alternatives do not include active treatment to reduce the toxicity, mobility, or volume of contaminants. VOCs occurring in the plumes would attenuate naturally over time.

The Source Control, Source Ex Situ and In Situ Treatment, Perimeter Control and Off Base Control, Source and Perimeter Control, Targeted Source and Perimeter Control, and Source Ex Situ and In Situ Treatment and Perimeter Control Alternatives (Alternatives 3 through 9) include active treatment that would reduce toxicity, mobility, and volume of contaminants in the groundwater. Each of the active remediation alternatives would remove or destroy about the same amount of VOCs over the life of the remediation activity. The Targeted Source and Perimeter Control Alternative would remove or destroy the least (about 440 lb) while the Source Ex Situ and In Situ Treatment, Perimeter Control and off Base Control Alternative would remove or destroy the most (about 530 lb).

Short-Term Effectiveness

There would not be any significant effects on workers, the community, or the environment during remediation for any of the nine alternatives.

The No Further Action and Monitored Natural Attenuation Alternatives would require the longest remediation time because they rely on no action and natural attenuation for remediation. For remediation of contaminated groundwater on base, the Source Ex Situ and In Situ Treatment, Perimeter Control and Off Base Control and Source Ex Situ and In Situ Treatment and Perimeter Control Alternatives may achieve remedial action objectives faster than Alternatives 3, 5, and 6 because they use in situ treatment which may eliminate contamination faster.

Implementability

All alternatives can be implemented, however, there are technical issues associated with the alternatives that involve active remediation (Source Control, Source Ex Situ and In Situ Treatment, Perimeter Control and Off Base Control, Source and Perimeter Control, Targeted Source and Perimeter Control, and Source Ex Situ and In Situ Treatment and Perimeter Control Alternatives [Alternatives 3 through 9]) related to the heterogeneous nature of the aquifer. The relatively low hydraulic conductivity and heterogeneities may make it difficult to extract groundwater in the area. The Source Ex Situ and In Situ Treatment, Perimeter Control and Off Base Control and Source Ex Situ and In Situ Treatment and Perimeter Control Alternatives, which include an in situ bioremediation component may have some difficulties in achieving uniform dispersion of substrates and/or nutrients into the aquifer. Alternative injection systems (such as dual-phase, horizontal two-pipe systems or recirculating wells) are not considered feasible because of the difficulty of reinjecting water into the low permeability subsurface.

In general, the Source Control, Source Ex Situ and In Situ Treatment, Perimeter Control and Off Base Control, Source and Perimeter Control, Targeted Source and Perimeter Control, and Source Ex Situ and In Situ Treatment and Perimeter Control Alternatives (Alternatives 3 through 9) all involve technologies, services, and materials that are readily available. In situ bioremediation (Source Ex Situ and In Situ Treatment, Perimeter Control and Off Base Control and Source Ex Situ and In Situ Treatment and Perimeter Control) is a relatively new and innovative technology, and most applications of this technology to date have been at relatively small remediation sites, and has not been proven on larger sites.

The Source Ex Situ and In Situ Treatment, Perimeter Control and Off Base Control Alternative requires the installation of wells located in off base areas and this could be difficult. The eastern section of Plume A is widely dispersed and is currently in a residential area. Because the plume is in a residential area, it will become increasingly difficult to install sampling wells. As the plume continues to disperse, this shortage of sampling wells will make it difficult to define the plume. Without a clear plume definition, properly installing off base recovery wells could become a problem.

Cost

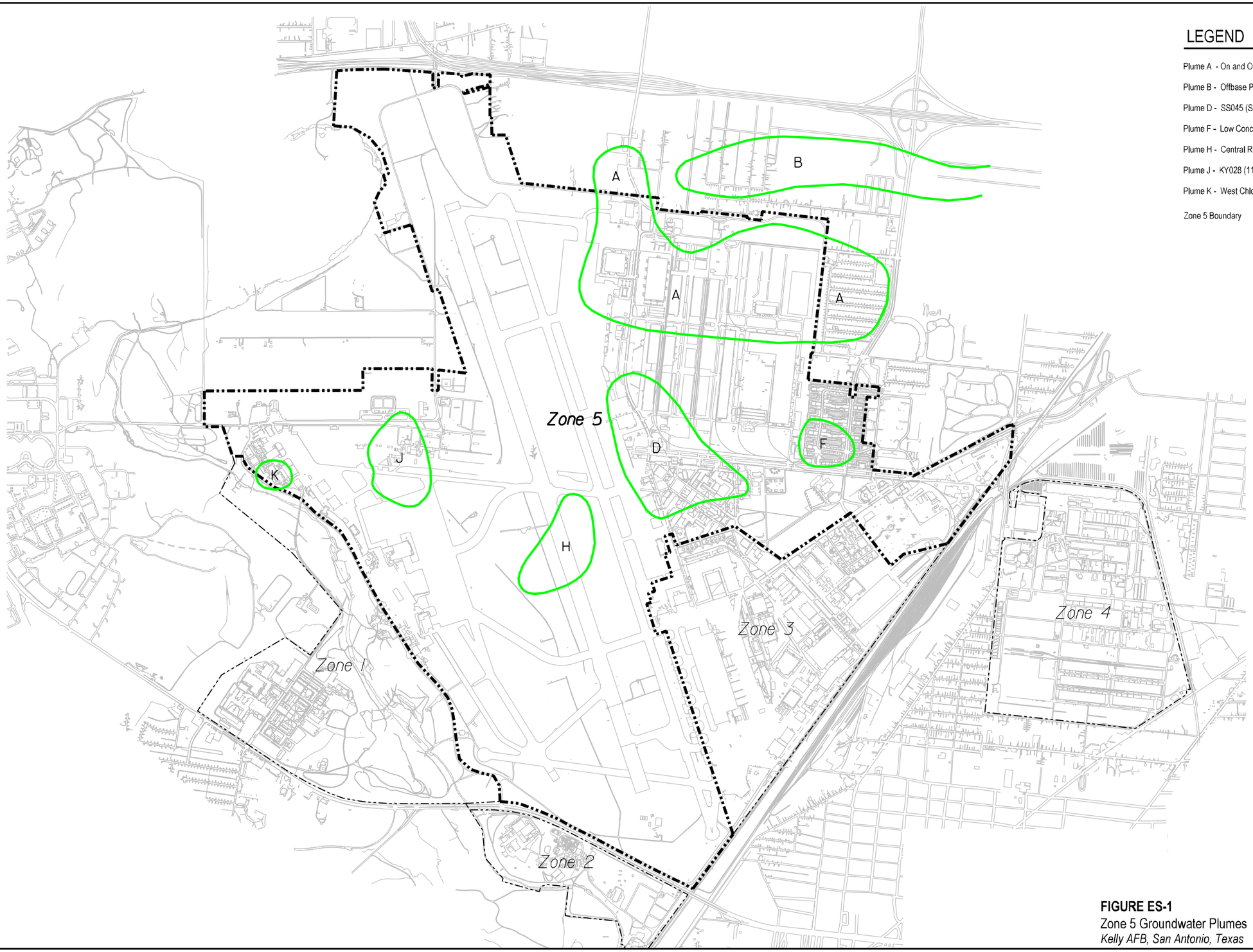
Table ES.1 presents the capital cost present worth for the nine alternatives. These cost estimates have been developed strictly for comparing the seven proposed alternatives. Final project costs will vary from the cost estimates. The specific details of remedial actions and cost estimates would be refined during final design. Project feasibility and funding needs must be reviewed carefully before specific financial decisions are made or project budgets are established to help ensure proper project evaluation and adequate funding.

The No Further Action Alternative has no cost. The cost for the Monitored Natural Attenuation Alternative is $1,590,000. The cost estimates for active remediation, the Source Control, Source Ex Situ and In Situ Treatment, Perimeter Control and Off Base Control, Source and Perimeter Control, Targeted Source and Perimeter Control, and Source Ex Situ and In Situ Treatment and Perimeter Control Alternatives (Alternatives 3 through 7), range between $6.94 and $10.2 million (Total project present worth).Alternatives 8 and 9, dealing only with Plume A, are $8.0 and $4.3 million, respectively.

NEPA Values

NEPA normally considers the environmental impacts of an action, such as impacts to environmental media, cultural resources, the ecosystem, and threatened and endangered species, as well as the cumulative impacts and any potential issues related to environmental justice. As indicated below, none of the alternatives would be expected to have significant environmental impacts:

- Kelly AFB is located in an attainment area for all pollutants with established national and state air quality standards (per the Air Quality Control Region 13 of the Air Quality Division of the TNRCC); none of the alternatives are anticipated to generate air emissions sufficient to jeopardize the federal attainment status of the region.
- There are no known or suspected archaeological sites on Kelly AFB, and none of the alternatives would impact any structures, buildings, or objects eligible for listing on the National Register of Historic Places, and subject to the National Historic Preservation Act (36 CFR part 800).
- Due to the urban development in the project area, there is very little natural habitat to support wildlife. Therefore, none of the alternatives would have a significant impact on sensitive, protected, threatened or endangered species. Zone 5 is also located outside of the 100-year flood plain; and there are no wetlands in or around the proposed project site.
- Because the construction activity related to these alternatives is extremely small and in an already industrialized area, and because no effects to cultural or ecological resources are anticipated, no significant cumulative impacts are anticipated from any of the remedial action alternatives.
- None of the alternatives would increase Kelly AFB's draw from the Edwards Aquifer, and, therefore, would not impact the threatened and endangered species associated with this sole source aquifer. NEPA requirements for public involvement are similar to those for remedial actions, and thus are covered under the standard IRP public comment process.



LEGEND

Plume A - On and Offbase TCE

Plume B - Offbase PCE

Plume D - SS045 (S-10) and 1600 Area TCE, PCE, 1,2-DCE

Plume F - Low Concentration PCE/TCE

Plume H - Central Runway TCE

Plume J - KY028 (1100 Area) PCE, TCE

Plume K - West Chlorobenzene

Zone 5 Boundary

N

0 1000' 2000' 3000'

AIRFORCE BASE CONVERSION AGENCY

FIGURE ES-1
Zone 5 Groundwater Plumes
Kelly AFB, San Antonio, Texas

CH2MHILL

TABLE ES.1
Summary of Costs for Zone 5 Groundwater Alternatives
Kelly AFB, San Antonio, Texas

Alternative	Description	Capital Costs ($ 000)	O&M Present Worth ($ 000)	Total Project Present Worth ($ 000)
Alternative 1	No Further Action	0	0	0
Alternative 2	Monitored Natural Attenuation	0	1,590	1,590
Alternative 3	Source Control	2,520	4,840	7,360
Alternative 4	Source Ex Situ and In Situ Treatment, Perimeter Control, and Off Base Control	4280	6,000	10,250
Alternative 5	Source and Perimeter Control	2,500	4900	7,400
Alternative 6	Targeted Source and Perimeter Control	2,230	4,700	6,940
Alternative 7	Source Ex Situ and In Situ Treatment and Perimeter Control	2,990	5,550	8,500
Alternative 8	In Situ Oxygen Treatment for Plume A Source and In Situ Perimeter Control	5,460	630	8,040
Alternative 9	In Situ Bioremediation Treatment for Plume A Source and In Situ Perimeter Control	3,420	230	4,360

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SECTION 1.0

Introduction

1.1 Purpose

Since 1991, a phased approach has been applied to remediation at Zone 5, which is one of five investigation zones (designated Zone 1 through Zone 5) that comprise Kelly Air Force Base (AFB). The phased approach has allowed remediation at Zone 5 to proceed on an accelerated schedule, thus mitigating potential adverse human health and environmental risk as expeditiously as possible. A primary goal of the phased approach has been to minimize or prevent further migration of shallow groundwater contamination past Zone 5, to the extent practical, and to address soil contamination at Installation Restoration Program (IRP) site SS003 (S-1), the location of a former intermediate storage area for wastes.

The purpose of this CMS is to evaluate final remedial alternatives for shallow groundwater contamination and off base shallow groundwater contamination in Zone 5. This CMS integrates the findings of previous focused feasibility study (FFS) reports addressing interim measures for shallow groundwater in Zone 5 with an evaluation of remedial alternatives for other Zone 5 areas of concern that have not been evaluated in previous reports. Thus, this document supports the remedy selection portion of the phased approach to remediation of Zone 5. It is anticipated that an alternative, or a combination of alternatives, will be selected from this CMS report by Kelly AFB and the regulatory agencies and presented in a separate proposed plan to the public for review and comment.

1.2 Background

Former Kelly AFB is located in San Antonio, Texas. The installation consists of two non-contiguous areas, the main portion of Kelly AFB and East Kelly. As a result of past waste management practices, the groundwater underlying and adjacent to the installation have become contaminated. To organize cleanup at the installation, former Kelly AFB is divided into five zones. Figure 1.1[1] shows Zone 5 in relation to the other four zones. Zone 5 consists of all on base areas outside of Zones 1 through 4. This CMS report is focused on evaluation of remedial alternatives at and immediately adjacent to Zone 5.

Former Kelly AFB is authorized for closure and post-closure care of certain waste units under Permit No. HW-50310 issued by the Texas Natural Resource Conservation Commission (TNRCC). Compliance Plan No. CP-50310 was issued in conjunction with

[1] All figures are at the end of each chapter in which they appear.

the Permit and requires the installation to conduct corrective action and groundwater monitoring programs to address contamination from past activities. Section I.C of the Compliance Plan lists solid waste management units (SWMUs) in Zone 5 that are subject to the state corrective action program and that must fulfill the applicable requirements of Section VIII of the Compliance Plan. Section VIII.E requires the installation to prepare and submit a CMS if it is determined that there has been a release of hazardous waste or hazardous constituents into the environment.

The cleanup of former Kelly AFB is also being addressed pursuant to Executive Order 12580, which directs United States Air Force (USAF) installations, among others, to conduct a cleanup program pursuant to the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) and the Department of Defense (DoD) Defense Environmental Restoration Program. The USAF program is called the IRP. The objective of the IRP is to assess past hazardous substance disposal and spill sites and to develop remedial actions for those sites that pose a threat to human health or the environment. The program is conducted consistent with CERCLA and the National Contingency Plan (NCP), even for those installations that are not on the U.S. Environmental Protection Agency's (EPA) National Priorities List (NPL). Former Kelly AFB is one of the installations being addressed under the IRP; it is not, however, on the NPL.

CH2M HILL has prepared this CMS report under contact to Kelly AFB, Contract No. F41624-900-D-8021-0085. The CMS report was prepared in accordance with the NCP and the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA, 1988), as well as the IRP and the *Resource Conservation Recovery Act of 1976* (RCRA) Compliance Plan for Kelly AFB. Additionally, this report has been prepared in compliance with the *National Environmental Policy Act of 1971* (NEPA).

1.3 Format and Organization of Report

Section VIII.E of the Compliance Plan requires the CMS report to identify and evaluate corrective measure alternatives and recommend corrective measures to protect human health and the environment. The purpose of the report is to address all of the items required by the EPA for RCRA CMS reports or their CERCLA equivalents (i.e., feasibility studies). In order to comply with the Compliance Plan and maintain the internal requirement of the Department of the Air Force to remediate sites under the CERCLA process, the contents of the CMS will comply with the requirements of both the RCRA corrective action and CERCLA remedial action processes. Thus, the format of this CMS report follows CERCLA/IRP guidance for feasibility studies, but is a CMS report written in conformance with the Compliance Plan. Table 1.1 identifies sections of this report that correspond to EPA's requirements for CMS reports.

This CMS report is organized into ten sections. Section 2 presents site information on former Kelly AFB and Zone 5, as well as a summary of historical and remedial

investigations (RI) in Zone 5. Section 3 summarizes site characteristics and describes the nature and extent of shallow groundwater contamination. Section 4 presents remedial action objectives (RAOs) and the development of preliminary remediation goals (PRGs) for groundwater. Section 5 describes the development and screening of remedial technologies and process options. Section 6 combines information from Sections 3, 4, and 5 and describes remedial alternatives for groundwater. Section 7 evaluates remedial alternatives developed against CERCLA criteria. Section 8 presents a listing of reports used to develop this CMS report. Key support information is presented in appendices attached to the report.

FIGURE 1.1
Kelly AFB IRP Zones
Kelly AFB, San Antonio, Texas

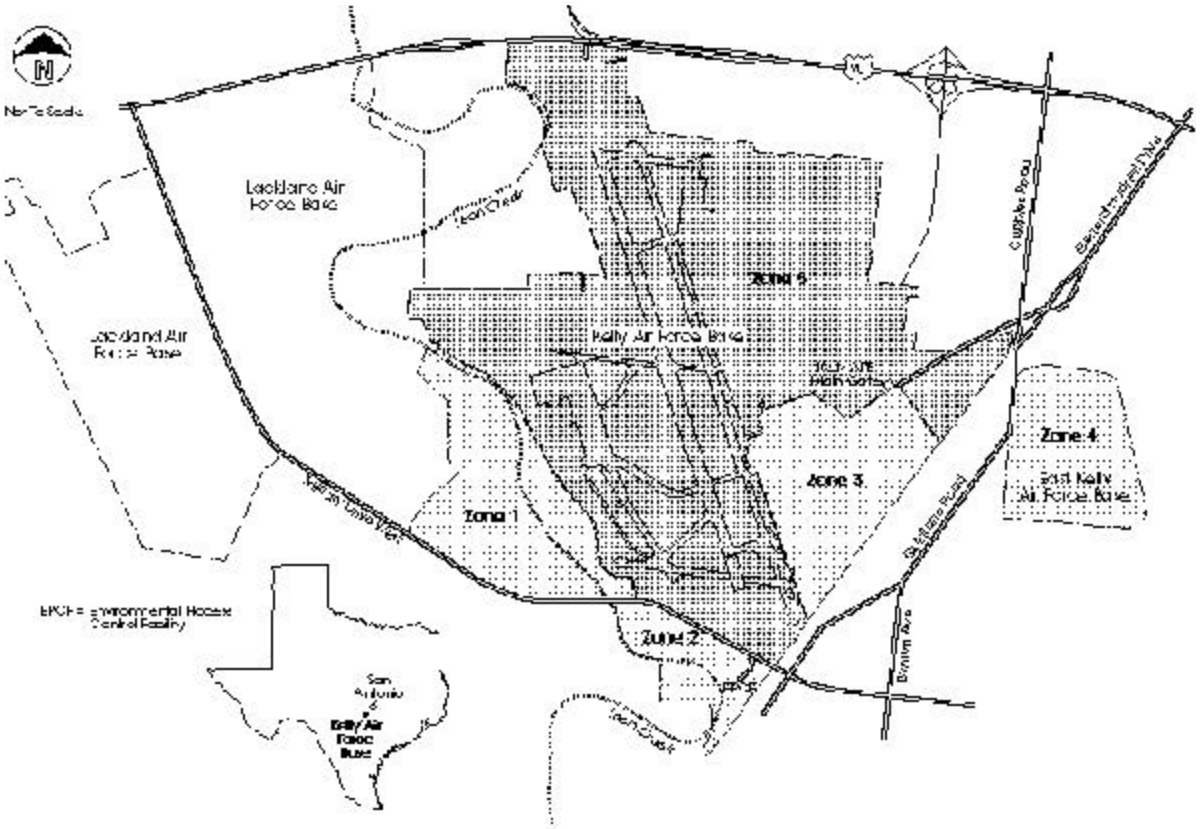

TABLE 1.1
Zone 5 Reports Addressing CMS Requirements
Kelly AFB, San Antonio, Texas

EPA Requirements for CMS Reports[1]	Zone 5 Report/Documents Where Requirements are Addressed
Corrective Measures Study Workplan	Zone 5 Remedial Investigation Report (see Section 2.3.1 of this report for summary)
Introduction / Purpose	CMS report (this document), Section 1.0
Description of Current Conditions	CMS report (this document), Sections 2.0 and 3.0
Correction Action Objectives	CMS report (this document), Section 4.0
Identification, Screening, and Development of Corrective Measure Alternatives	CMS report (this document), Sections 5.0 and 6.0
Evaluation of a Final Corrective Measure Alternative	CMS report (this document), Section 7.0
Recommendation by a Permittee / Respondent for a Final Corrective Measure	CMS report (this document), Section 8.0
Public Involvement Plan	Kelly AFB program-wide public involvement plan (currently in preparation)
Proposed Schedule	Final BRAC Cleanup Plan (CH2M HILL, 1997a) and Final Management Plan (CH2M HILL, 1997b)

[1] From USEPA, 1994a

SECTION 2.0

Site Information

2.1 Installation History

Established on 7 May 1917, Kelly AFB was the oldest continuously active airfield in the United States Air Force (USAF). The base's primary mission was to support the San Antonio Air Logistics Center (SA-ALC). The SA-ALC was one of the major Air Force Materiel Command organizations providing large-scale logistics support to USAF installations worldwide. The center managed aircraft engines, weapons systems, support equipment, and aerospace fuels. Also, many aircrafts were maintained and repaired at Kelly AFB. Kelly AFB also hosted more than 50 tenants representing the USAF, United States Army, Department of Defense (DOD), and other government agencies.

Kelly AFB was recommended for realignment and closure by the 1995 Defense Base Realignment and Closure Commission. The Commission's recommendations were accepted by the President and submitted to Congress on 13 July 1995. As Congress did not disapprove the recommendations in the time given under the Defense Base Realignment and Closure Act of 1990, the recommendations are required by law to be implemented. Kelly AFB closed on 13 July 2001. The flightline and areas west were realigned to Lackland AFB (LAFB) in 2001 and became the Kelly Annex of LAFB.

A Programmatic Disposal Environmental Impact Statement (PDEIS) was developed to evaluate the impacts associated with the disposal and subsequent reuse of the portions of Kelly AFB east of the airfield as well as an area to the south of Military Highway. The Record of Decision (ROD) for this PDEIS, as well as an Economic Development Conveyance, and Lease in Furtherance of Conveyance for the property to be transferred to the Greater Kelly Development Authority (GKDA) were signed on 24 July 1997. The Economic Development Conveyance is the contract through which the property will be transferred to the GKDA once all necessary remedial actions have been installed by the Air Force and are determined to be operating successfully.

Kelly AFB initiated environmental restoration activities in 1982 under the USAF's Installation Restoration Program (IRP). The purpose of the IRP is to identify and remediate historically contaminated sites following the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process. For the IRP, Kelly AFB is divided into five groundwater zones (Figure 2.1). To date, 52 IRP sites associated with past base operations have been identified in these five zones.

Several investigations and remedial activities have been completed at Kelly AFB. Between 1982 and 1988, IRP activities primarily comprised preliminary assessments (PAs) and site investigations (SIs). Since 1988, IRP activities primarily have involved remedial investigations and feasibilities studies (RI/FSs) that characterize the nature and extent of constituents in soil and groundwater at the IRP sites, evaluate risk to human health and the environment and evaluate remedial alternatives. In 1989, the Texas Water Commission

(TWC), which is now the TNRCC, issued an order that provided a schedule for restoration activities. On 12 June 1998, the TNRCC issued to Kelly AFB a Hazardous Waste Permit and Compliance Plan that superceded the order.

2.2 Zone 5 Background Information

2.2.1 Site Description and Former Waste Disposal Practices

Zone 5 includes all areas and facilities in the central part of the base and the flight line. It covers an area of about 2,600 acres, which is about 54 percent of Kelly AFB. The northern part of Zone 5 includes a warehouse area constructed in the late 1940s; the Directorate of Nuclear Weapons; a small aircraft maintenance hangar along the east edge of the flight line; the Defense Logistics Agency, which stores materials; and warehouses operated by various tenant organizations. Alamo Aircraft, a private military surplus company, occupies several blocks off base north of Zone 5 and includes warehouses and storage yards. The North Kelly Gardens residential area is located off base to the north. The Jamar Village residential development is located east and north of the northern property line of the base, and north of Billy Mitchell Road.

The southern part of Zone 5 has no buildings but includes most of the flight line. Historically, this part of Zone 5 has been used for flight line-related activities, including storage and maintenance of aircraft as well as flight operations.

The western part of Zone 5 includes facilities operated by the 149th Texas National Guard, the 433rd C-5 Air Wing of the Air Force Reserve, and a bulk fuel storage facility north of the 149th compound. Other operations include the fire training area. In the 1940s, the Kelly AFB field runway was located along a line parallel to Billy Mitchell Road. During this time, the area north of Billy Mitchell Road was initially an open field and later used for surplus aircraft storage after World War II. The portion of the flight line in the western part of Zone 5 contains most of the original east-west oriented flight line and its associated maintenance area.

Elevations in Zone 5 range from about 638 feet to 696 feet above NGVD. The highest elevations are in the extreme northwest part of Zone 5 where a small ridge extends southeast. The topography gently slopes away from this ridge to the southwest and southeast. The lowest elevations occur in the southern part of Zone 5. A large drainage ditch discharges to Leon Creek along the west side of Zone 5.

The eastern part of Zone 5 includes many of the base administration buildings. Historical aerial photographs show that many of the current administration buildings were constructed prior to World War II. The area north of Billy Mitchell Road was used for agricultural purposes.

2.2.2 Former Spills and Unplanned Releases

Historical spills and unplanned releases at Zone 5 facilities are designated as IRP sites. Zone 5 includes six IRP sites that are listed in Table 2.1 and shown on Figure 2.2. Zone 5 also contains one waste management area (WMA), the SS003 (S-1) WMA, and two areas of concern (AOC), the KY028 (1100 Area) AOC and the KY029 AOC. The WMA is an

unplanned release site located directly upgradient of an operating interim recovery system. The WMA and AOCs are also identified in Table 2.1 and on Figure 2.2.

The following are brief descriptions of historic spill and unplanned release sites located in Zone 5, and their current status.

2.2.2.1 IRP Site SS003 (S-1)

Site SS003 (S-1), a WMA, is a former waste oil storage facility and the former Defense Property Disposal Office storage area. It is located south of Growden Road adjacent to the 1500 Area. The site was used from the 1960s to 1973 for intermediate storage of wastes, including mixed solvents; carbon cleaning compounds; and waste petroleum, oils, and lubricants. During the 1960s and 1970s, polychlorinated biphenyls (PCBs) frequently were mixed with dielectric fluids, usually chlorobenzene (CB), and used in electrical transformers. The western two-thirds of the site were used for temporary storage of electrical transformers and scrap metal (Radian, 1984).

Historical spillage from aboveground tanks accumulated in a former depression referred to here as the sump area. Contaminated soil at site SS003 (S-1) occurs in the former sump area and in a smear zone (12 to 24 feet bgs) in the zone of water table fluctuation surrounding and downgradient from the former sump. An interim measure shallow groundwater recovery system consisting of six recovery wells and an air stripping system was installed and has been in operation since March 1995. The system seems to be relatively effective in helping mitigate the migration of groundwater contamination off base. Soils were addressed as an interim action in 1998 and include soil excavation at the sump area and offsite disposal and installation of a dual phase groundwater recovery and SVE for the smear zone. Groundwater contamination at this IRP site is being addressed under the Permit and Compliance Plan and is discussed in this CMS report.

2.2.2.2 Site ST007 (S-5)

Site ST007 (S-5) is located behind Building 1618 along the eastern side of the flight line and south of Billy Mitchell Road. Operations began at this location in 1926. It is a former Aqua Fuels System consisting of eight 25,000-gallon and two 10,000-gallon underground storage tanks, eight 500-gallon sump tanks, and two distribution lines. The fuel system was constructed around 1926 and was originally used to store and dispense aviation gasoline (AVGAS). The system was converted to jet fuel around 1950. However, AVGAS continued to be stored in the storage tanks. Truck stands were used to dispense both types of fuel until the system was closed. From 1970 to July 1993, petroleum products including jet fuel, control unit calibrating fluid, and waste oils were stored in the 10,000-gallon petroleum storage tanks (PSTs). All 18 underground storage tanks were removed during July and August 1993.

Groundwater in the vicinity of this site is contaminated with petroleum products; co-contaminants are not known to be present. Monitored natural attenuation of groundwater, the alternative recommended in the FS for this site (Halliburton NUS, 1993), was approved by the TNRCC. On November 19, 1993, the TNRCC approved closure of site ST007 (S-5) under 30 TAC 334 and indicated that no further remedial action is required at

this time. The site is now closed (Raba-Kistner, 1994a) and will not be discussed further in this CMS report.

2.2.2.3 IRP Site SS025 (IS-1)

Site SS025 (IS-1) is a spill area in the location of a former solvent still that operated between 1955 and 1972. The still was located on the northern side of Building 1414 and was used for the recycling and recovery of spent solvents associated with degreasing and cleaning activities. There are no physical remnants of the still or still operations. Base employees suggest that the primary solvent at the site was trichloroethene (TCE) and analytical results have shown the presence of TCE in groundwater. Closure of the SS025 (IS-1) soils has been approved by TNRCC. Groundwater contamination in the area of SS025 (IS-1) is being addressed under the Permit and Compliance Plan. The area currently is used for industrial activities.

Early site investigations at site SS025 (IS-1) were conducted in 1989 by Chen-Northern, Inc., and are described in SWL (1992a). Additional investigations by Southwestern Laboratories (SWL) are documented in SWL (1992a). These investigations were focused primarily on soil contamination in the immediate vicinity of the former solvent still. Data resulting from these investigations are summarized in Appendix A. More recently, CH2M HILL conducted investigations during 1997 at strategic locations in Zone 5 (including the SS025 [IS-1] area) to assess whether leaking underground sanitary sewers in Zone 5 have been a potential source of contamination to the soil and groundwater. The methodology and results for the 1997 Zone 5 sewer line investigations, including maps showing exploration locations, are summarized in Appendix B. In the Building 1414 area, the investigations consisted of collection of 40 soil gas samples and 10 soil samples from soil used as backfill material for sewer trenches. The samples were analyzed on-site for chlorinated volatile organic compounds (CVOCs) immediately after collection.

Analytical results for soil gas indicate the presence of TCE at concentrations up to 15 μg/L and TCE degradation products at concentrations up to 60 μg/L in the area of Building 1414. Total xylenes were also detected at 360 μg/L. These were the highest levels of soil gas contaminants that were identified during the sewer investigation. No contamination was detected from samples collected from outside of the sewer trench, suggesting that soil gas contamination detected along the sewer trenches is localized along and related to releases from the sewer lines.

These data, discussed in greater detail in Appendix B, suggest the sanitary sewer at the Building 1414 may have been a point of release for contaminants during years of operation for the former solvent still. Additional soil and groundwater samples were collected during the RI supplemental investigation (Appendix E). Soil Site IS-1 (Solvent Still) was approved for closure by the TNRCC. Contaminated groundwater in the vicinity of Building 1414 is being addressed by the CMS as part of Site SS050.

2.2.2.4 IRP Site SS045 (S-10)

Site SS045 (S-10) is a reported fuel spill site. It is an area of soil and groundwater contamination that was discovered during environmental investigations for site ST007 (S-5) and is located near the flight line between buildings 1600 and 1610. Site S-10 previously contained three above-ground petroleum storage tanks (ASTs), comprised of one 200-gal and two 500-gal tanks. The two 500-gal ASTs reportedly contained mo-gas, and the 200-gal

AST initially contained diesel, and finally, contained JP-4 fuel. These three ASTs were removed several years ago. Soils in the vicinity of the ASTs were excavated to a depth of approximately 1.5 ft below ground surface (bgs). The S-10 area has been used primarily as an alternate power unit (APU) maintenance area.

During a limited subsurface investigation performed by IHS Geotech & CMT, Inc., traces of chlorinated solvents, TCE, and PCE in particular, and other VOCs were detected in soils and groundwater beneath the site (IHS Geotech, 1991). A site investigation and preliminary risk assessment, which included geoprobe soil gas sampling, soil sampling and groundwater sampling was conducted by Raba-Kistner (1994b). The conclusions of this report follows:

- The horizontal extent of contamination has been defined to the north, east and west.
- The vertical extent of contamination has not been fully characterized.
- The preliminary risk assessment determined that the total chronic hazard indices of exposure under current and future land use are both less than one, indicating an insignificant non-carcinogenic health risks at the site. The cancer risks at the site are acceptable under RCRA.

Additional soil and groundwater samples were collected during the RI supplemental characterization investigation (Appendix E). Groundwater in the vicinity of this site is contaminated with petroleum products (benzene, toluene, ethylbenzene, and xylene (BTEX) compounds) and with tetrachloroethene (PCE). Due to the presence of PCE as a co-contaminant, the contaminated groundwater is being addressed under the Permit and Compliance Plan and is addressed in this CMS report. A Risk Reduction Standard 2 Closure Report was submitted to the TNRCC in December 2001.

2.2.2.5 ST049 (Building 38 Area)

The underground storage tank system at the Civil Engineering Motor Pool was installed in 1950 and consisted of six underground storage tanks, four of which (one 500-gal, one 10,000-gal, and two 5000-gal) were removed in December 1992. During tank removal at the site, over-excavation was performed where necessary to assess limits of contamination and remove contaminated soils. A site closure report for the four tanks removed in 1992 was submitted to the TNRCC in June 1994. Because over-excavation did not achieve TNRCC soil action levels for one of the tanks, further assessment of the site as a leaking PST site was warranted (TNRCC, 1993). A final supplemental closure summary and risk assessment report was subsequently submitted to TNRCC in April 1995 (PES, 1995). The remaining tanks were removed in December 2001.

The groundwater in the vicinity of this site is contaminated with petroleum products (BTEX compounds) and will be closed under 30 TAC 334.

2.2.2.6 IRP Site SS050 (OT-50)

Site SS050 (OT-50) is a solvent spill site located at Building 1414. It originally consisted of groundwater contamination and may be associated with Site SS025 (IS-1). The designation SS050 has since been expanded to include all groundwater in Zone 5. Individual contaminated groundwater plumes in Zone 5 are being addressed under the Permit and

Compliance Plan with the exception of groundwater at unplanned release sites contaminated only with BTEX compounds. All PST related sites, even those in the permit and compliance plan, are being closed under 30 TAC 334 rules, unless industrial waste is comingled with the site. If industrial waste is present in the plume, then provisions of the Permit and Compliance Plan will be used.

2.2.2.7 KY028 (1100 Area)

The KY028 (1100 Area) AOC is a spill site west of the flight line and north of the 433rd Air Lift Wing, where 80,000 gallons of JP-4 jet fuel is reported to have been released from a high-pressure supply line on June 14, 1988. As an interim action, the soils at the site were remediated utilizing bio-venting and soil vapor extraction (SVE) systems. TNRCC granted site closure on July 9, 1998.

The analytical results from the recent groundwater sampling events (CH2M HILL, 2001) indicate that, in addition to BTEX compounds, the groundwater in the spill area is also contaminated with TCE, PCE, dichloroethene (DCE) and vinyl chloride (VC). Because of the presence of these co-contaminants, groundwater contamination will be addressed under the Permit and Compliance Plan and is discussed in this CMS report.

2.2.2.8 KY029 (1500 Area)

The KY029 (1500 Area) AOC is a JP-4 spill site. In September 1991 a release was discovered at the low point drain valve for the underground, pressurized JP-4 pipelines which parallel the north side of West Thompson Road. During the initial site assessment it was estimated that less than 1000 gallons of JP-4 were released (SWL 1992b). The site is an open, grassy field with two underground JP-4 fuel pipelines. The pipelines are buried about 6 to 8 ft below grade. Contaminants in the soil at this site include total petroleum hydrocarbons (TPH) and BTEX. A bio-venting system was in operation in this area from October 1993 to January 2001. The system was removed in October 2001. (SAIC, 1995). Because releases from the AOC were limited to petroleum products, contaminated soil at this AOC is being remediated under a the 30 TAC 334 rules..

2.3 Summary of Historical and Remedial Investigations

Several investigations have been conducted to evaluate the origin, nature, and extent of environmental contamination at former Kelly AFB. A review of recorded chain-of-title documents and reviews of historic information regarding prior land use do not indicate that any of the environmental concerns existing on former Kelly AFB can be attributed to uses of properties prior to purchase by the U.S. Government.

Environmental restoration activities under the USAF's IRP began at Kelly AFB in 1982 and focused on preliminary assessments and site inspections. Since 1988, RI activities have focused on characterizing the nature and extent of compounds in soil and groundwater at the 52 IRP sites identified to date. To manage restoration activities, Kelly AFB has been divided into five IRP zones. In 1989, the Texas Water Commission (now TNRCC) issued an order establishing requirements for restoration of the base. Additionally, under the TNRCC-proposed post-closure care permit application and associated compliance plan,

14 WMAs were designated. The WMAs are typically located around IRP sites with operating interim remedial action systems. There is one WMA in Zone 5 (site SS003 [S-1]). Each WMA has an associated downgradient area, consisting of the constituent with the furthest downgradient plume extent.

2.3.1 Remedial Investigation

Comprehensive RI studies were conducted at Zone 5 during 1995 and 1996. The goals of the RI studies included:

- Identifying the nature and extent of contaminants, sources, and the vertical and horizontal extent of the contamination
- Providing enough information so that the next phase of work (this document) can evaluate cleanup options and begin the process of setting priorities for remediation of Zone 5.

The resulting Final RI report (CH2M HILL, 1999) summarizes the results of the RIs and evaluates in a baseline risk assessment whether contaminated media pose a threat to human health or the environment. The Zone 5 RI report also identifies the preliminary regulatory standards for comparison. The Zone 5 RI report constitutes the primary source of data used for this CMS report. Data from the RI report are supplemented, where necessary, by supplementary or more recently acquired data, as identified and described in this report (Section 2.4).

Because Zone 5 is the largest of the five IRP zones at Kelly AFB and covers more than half of the base area, for purposes of conducting RIs it was divided into four study areas designated the North, South, East and West Study Areas. The RI report presents results for each Study Area in Zone 5. The "Study Area" nomenclature has not been maintained in this CMS report except where necessary to summarize key data or findings presented in the RI report. Instead, individual IRP sites and groundwater plumes are discussed in this CMS report without regard to which RI report quadrant(s) in Zone 5 they may be located.

2.3.2 Site SS003 (S-1) Investigations

Site SS003 (S-1) has been the focus of several RI and several FFS reports in support of initiating interim measures for groundwater and soil. Investigation of site SS003 (S-1) began with Phase I and Phase II IRP investigations in 1983 and 1986. Table 2.2 provides a summary of soil sampling conducted at site SS003 (S-1). Soils in the sump area and smear zone have been addressed as an interim action. Soils will not be addressed as part of this CMS. Groundwater data are addressed in Section 3.

The RI report documenting the site SS003 (S-1) characterization activities was prepared in 1994 (Halliburton NUS, 1994a). Additional soil sampling was conducted to further characterize soils in site SS003 (S-1) following the RI activities. The RI report documenting the characterization of soil and groundwater contamination during the Zone 5 RI activities was prepared by CH2M HILL (1999). An FFS report addressing the activities for interim measures for on base groundwater was finalized in 1994 (Halliburton NUS, 1994b) A Zone 5 FFS report addressing off base shallow groundwater contamination migration beyond portions of the northern and eastern Kelly AFB property boundary was prepared by CH2M HILL (1997c).

The primary contaminants detected as a result of the soil sampling events identified in Table 2.2 were some pesticides, shallow PCBs associated with former transformer areas, and CB, 1,2-dichlorobenzene (1,2-DCB), and 1,4-dichlorobenzene (1,4-DCB). The CB, 1,2-DCB, and 1,4-DCB detected were associated primarily with past waste management practices occurring in a former depression area referred to as the former sump (depression) area. An area of soil contamination within the zone of shallow aquifer water level fluctuations is referred to as a "smear zone." The primary groundwater contaminants detected through historical groundwater monitoring activity include arsenic, benzene, CB, 1,4-dichloroethene (1,4-DCE), and TCE.

A Final FFS report (CH2M HILL, 1998c) has been prepared to evaluate remedial alternatives for soil contamination at site SS003 (S-1). The objectives of the report were to develop and present an interim measure for soils that is protective of public health and the environment. A secondary objective was to achieve closure of site SS003 (S-1) under Texas Risk Reduction Standard 3. The excavation and offsite disposal alternative for contaminated soil at the former sump area and the dual-phase groundwater recovery and SVE alternative for the "smear zone" have been implemented as an interim action. As proposed in the 1994 FFS (Halliburton NUS, 1994b), an interim measure shallow groundwater recovery system consisting of six recovery wells and an air stripping system was installed and has been in operation since March 1995.

2.3.3 Other Zone 5 Investigations and Studies

Table 2.3 summarizes Zone 5 environmental investigations and studies (not including the Zone 5 RI [CH2M HILL, 1999] and studies focused on site SS003 [S-1]).

2.3.3.1 Annual Basewide Remediation Reports

An annual basewide remedial assessment (BRA) evaluates the effectiveness of ongoing remedial activities on the quality of the surficial groundwater. The annual report evaluates the results of basewide groundwater sampling and analyses and compares data presented in previous reports and RIs. Compliance monitoring activities have continued each year through to 2000.

2.3.3.2 Natural Attenuation Studies

A natural attenuation study Parsons Engineering Science, Inc. (PES 1998) was performed to evaluate natural biodegradation of CB-contaminated groundwater at site SS003 (S-1). The study used finite-difference modeling in conjunction with site-specific geologic, hydrogeologic, and laboratory analytical data to simulate the migration of CB dissolved in groundwater. The results of the model indicated that the CB plume at site SS003 (S-1) currently is stabilized by the effects of natural attenuation. Although modeled CB concentrations are predicted to be greatly diminished as a result of source remediation activities at site SS003 (S-1), the model predicts that CB concentrations above the Texas Risk Reduction Standard (RRS) 2 of 100 µg/L may remain until calendar year 2035 at wells closest to the perimeter of Kelly AFB. This estimate is based on an assumption that source remediation at site SS003 (S-1) would begin in the year 1999 and continue for 4 years and that the existing groundwater collection system would no longer be operated.

2.3.3.3 Chain-of-Title Search

A recorded chain-of-title search has been conducted for on base parcels to determine prior ownership and uses that could reasonably have contributed to an environmental concern. The title search reviewed DoD acquisition of on base parcels since 1917. The survey of the Bexar County property records indicated that all owners of the respective parcels owned their land for at least 10 years before purchase by the U.S. Government, and all former owners have been identified in the title search. A review of recorded chain-of-title documents and a review of historic information regarding prior land use has previously been performed. Neither review indicated that any of the environmental concerns existing on Kelly AFB can be attributed to uses of properties prior to purchase by the U.S. Government. Various RI studies that have been conducted also indicate that some of the contamination on base might have an off base point source. These issues are part of an ongoing basewide remediation effort.

2.3.4 Petroleum Storage Tanks

There are 44 PST sites in Zone 5 (Table 2.4), many of which have undergone some level of investigation and/or remediation. As indicated in Section 2.2.2, Zone 5 IRP sites ST007 (S-5), ST049 (B38), and AOC sites KY028, and KY029 are unplanned release sites that have been or are being addressed under a 30 TAC 334 rules. The following additional PST sites and associated building numbers in Zone 5 have been closed or are in the closure process:

- **Building 894:** Two PSTs, a 1,000-gallon diesel tank and a 1,000-gallon mogas tank, were removed in September 1994. A closure report has been submitted to TNRCC.
- **Building 1594:**. A 500-gallon JP-4 PST was removed in 1994 and replaced by a 1,000-gallon vaulted tank. A site assessment has been conducted. TNRCC has requested further investigation.
- **Building 1674:** A 550-gallon diesel PST was removed in 1992 and a 7,000-gallon diesel PST was removed in 1994. A closure report has been submitted to TNRCC for the 550-gallon PST. A site assessment has been conducted for the 7,000-gallon PST. As of April 1996, TNRCC is requiring quarterly monitoring at this site.

The North Fuel Hydrant System was permanently removed from service (abandoned in place) July through August 2000, and a closure report submitted in September 2001 to the TNRCC for closure under 30 TAC 334. The South Fuel Hydrant System was permanently removed from service (abandoned in place) July through August 2000, and a closure report submitted in December 2001 to the TNRCC for closure under 30 TAC 334.

2.4 Supplemental Investigations

2.4.1 Introduction

The primary data base for this CMS report is the Zone 5 RI report (CH2M HILL, 1999). Since preparation of the Zone 5 RI report, however, several supplemental investigations have been conducted for Kelly AFB in general and, in some cases, specific to Zone 5. This section identifies and briefly describes supplemental evaluations conducted at Zone 5 since completion of the Zone 5 RI.

2.4.2 Seismic Reflection Survey/Top of Navarro Structure Contour Map

A seismic reflection survey was conducted in Zone 5 in August 1996 to estimate the depth of Navarro Group and to provide data to be used in the preparation of a contour map depicting topography on the top of Navarro Group. Fieldwork was conducted in two phases: velocity check shot survey and field production. The purpose of the velocity check shot survey was to determine the velocities necessary for time-depth conversion during data reduction. Velocity check shot surveys were completed at eighteen shallow borings in Zone 5. Field production included collection of reflection data along 23 seismic reflection lines. Each seismic line consists of a series of shotpoints acquired at a predetermined interval (10 feet). Some of the seismic lines were separated into sub-units for the ease of data processing and general data handling. The locations of the eighteen shallow borings and the 23 seismic reflection lines and shotpoints are shown in Figure 2.3.

After data processing, seismic reflection profiles were developed by ***Interpre' Tech/SeisPulse LLC*** and are located in CH2M HILL project files. Data were converted to the depth to the top of the Navarro Group using average velocities of 1,575 ft/sec or 2,000 ft/sec. Calculated depths were then compared with the actual Navarro depths in areas where seismic lines cross or are close to the shallow soil borings. Deviations in depth between calculated and actual depths were indicators of the seismic survey accuracy. With few exceptions, seismically derived depths were within 10 percent or less of depths derived from borehole data. A contour map showing the configuration of the top of Navarro Group was then developed using the seismic reflection data and data from Zone 5 soil borings. The resulting contour map is shown in Figure 2.4. Details of the seismic survey are presented in Appendix D.

2.4.3 1994-2000 Basewide Groundwater Sampling

Compliance plan monitoring reports (CPs) are prepared annually to evaluate the effectiveness of ongoing groundwater remediation efforts and recommend future actions at former Kelly AFB. Historically each year analytical data from about 400 to 600 wells have been used to describe the distribution of organic parameters in the surficial aquifer at former Kelly AFB and surrounding areas. The most recent CP data were collected in 2001 and have not yet been published.

2.4.4 Mini-Well Investigation at the 149th Air Wing

Screening-quality groundwater data were acquired during 1997 from nine mini-wells (MW) installed by Science Applications International Corporation (SAIC) along Westover Road, near the 149th Air Wing. Additionally, two groundwater monitoring wells were installed in the 149th Air Wing compound. Mini-well information, including horizontal and vertical coordinates, is summarized in Table 2.5.

The MWs were completed to aid in the delineation of the contamination that was detected in monitoring well SS050MW149, where elevated levels (420 µg/L) of CB were detected during sampling for the 1997 BRA (CH2M HILL, 1998b). Only one mini-well, SS050SV350, indicated contamination above detection limits; contaminants consisted of BTEX and TPH.

2.4.5 Sanitary Sewerline Investigation

In 1997, investigations were conducted to collect and analyze soil gas and soil samples from selected locations along sanitary sewer lines within Zone 5. While no specific sources are known, the purpose of the investigations was to determine whether leaky sanitary sewers are a source of soil and groundwater contamination. A total of 141 soil gas samples were collected from five areas along the Zone 5 sewer lines. The soil gas samples were analyzed for volatile aromatic and halogenated hydrocarbons. A total of 11 soil samples were collected from two of the five study areas and were analyzed for volatile aromatic and halogenated hydrocarbons. A detailed description of the sewer line investigation, including location maps for areas explored and a data summary package, is included in Appendix B.

The investigation concluded that leaky sanitary sewer lines may have been a source of contamination and that contaminated soil may exist at or below these areas. This is especially true for the Building 1414 area, located adjacent to site SS025 (IS-1) (Figure 2.1), which had the highest levels of soil gas contaminants (TCE and total xylenes at concentrations up to 15 µg/L and 360 µg/L, respectively). Soil samples collected in the same vicinity of the soil gas contamination, however, did not show levels of contamination that were of concern. This finding does not rule out the sanitary sewers as a possible source.

No contaminated soil source sites were identified as a result of this investigation. However, these data suggest that leaky sanitary sewer lines at the Building 1414 may have been a point of release for contaminants during years of operation for the former solvent still at site SS025 (IS-1).

2.4.6 Surface Soil Sampling at Building 1592 Area

One hundred and eight soil samples were collected during late 1996 in the area of Building 1592 in support of risk assessment work for Kelly AFB (CH2M HILL, 1997e). The soil samples were collected from the surface to a total depth of 2 ft. In early 1997, additional soil samples were collected from shallow borings up to 5 feet deep. Samples were analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), PCBs, and metals.

2.4.7 Soil Sampling at Site SS003 (S-1)

2.4.7.1 SAIC Borings

Seven soil borings were drilled in 1996 and an additional three were drilled in 1997 at site SS003 (S-1) by SAIC . A total of 37 soil samples were collected from the surface to a total depth of 36 ft bgs. Samples were analyzed for metals, VOCs, PCBs, and SVOCs.

2.4.7.2 CH2M HILL Soil Borings

Ten borings were located across site SS003 (S-1) to further evaluate the nature and extent of soil contamination in the area. The soil borings were drilled by CH2M HILL in late 1997 and are reported in the site SS003 (S-1) FFS for soil (CH2M HILL, 1998c). A drill rig was used during the field investigation and advanced boreholes with a 4 ¼-in. hollow-stem auger and with a split-spoon wireline assembly. Borings were drilled to a maximum depth of 26 ft bls or until the water table was encountered. A total of 30 soil samples were collected from

the borings. Samples were analyzed for alkalinity, TPH, sulphates, total organic carbon (TOC), metals, SVOCs, VOCs, pesticides, and PCBs.

2.4.8 Zone 5 RI Supplemental Characterization

A total of twelve additional soil borings and sixteen additional monitoring wells were drilled in late 1998 to conduct a supplemental investigation in support of the Zone 5 RI report (CH2M HILL , 1999). The wells and borings were used to provide additional soil and groundwater data for four separate locations in Zone 5. Twelve wells were used to further define the extent of the off-base contaminant plume north of the former Kelly AFB. Four wells and 12 borings were used to further evaluate a potential source in the vicinity of Building 1414 and define the limits of contamination associated with the SWMU at Building 1418 (oil water separator). The monitoring wells, located on base and off base, further defined the extent of existing groundwater contamination. Appendix E contains maps with the locations of the monitoring wells and soil borings.

2.4.9 Zone 5 Exploration (Pre-Design) Borings

A total of sixteen soil borings were drilled in Zone 5 during February 2001. Ten of the borings were drilled in the source area, and the remaining six borings were drilled along the installation boundary. The borings were initially designed to explore the possibility of an aquifer pump test for a collection trench and a recovery system. The results of the borings indicate that groundwater is very sparse and that an aquifer pump test, as well as groundwater collection, is probably not a viable option.

2.5 Other Areas Under Evaluation

In addition to the IRP sites, AOCs, and PSTs discussed in this document, several solid waste management units (SWMUs) and other areas are under evaluation in Zone 5. These are sites that in the past, have handled or managed some type of waste stream. These areas are identified in one or more of the following documents: Kelly's Groundwater Compliance Plan, Texas Notice of Registration, EPA 1988 RCRA Facility Assessment, or the 1996 Kelly Realignment Environmental Baseline Survey. Closure activities for six of these sites began in 1994. With the announcement of the closure and realignment of Kelly AFB, many of the other units have or will become inactive. Closure activities for some of these units began in 1996 and are at various stages of completion. Table 2.6 contains a description and status of each of the additional areas under evaluation as well as any future activities planned or required for closure.

2.6 Interim Remedial Actions

Remedial activities undertaken within Zone 5 have been interim actions with a primary purpose being to minimize off base migration of CVOCs and metals found in the surficial aquifer beneath Kelly AFB. The primary measure of the effectiveness of these remedial activities is a reduction in the concentration and/or extent of these compounds at off base monitoring locations. A summary of the interim actions is presented in Table 2.7. The following is a description of interim remedial actions in Zone 5.

2.6.1 SS003 (S-1) Groundwater Treatment System

The SS003 (S-1) system, which includes six groundwater recovery wells, was installed to prevent additional off base migration of spent solvents and chlorinated hydrocarbons. Site SS003 (S-1) is a former waste oil storage facility and the former Defense Property Office storage area. The flow rate from the SS003 (S-1) groundwater recovery system is about 2 gallons per minute (gpm) during full system operation. The system's average flow rate (including operating and non-operating periods) was about 1.91 gpm from August 1996 to August 1997. When compared to the 1996 CB distribution, the 1997 CB distribution suggests that the S-1 recovery system may have affected a separation between the on and off base sources. In addition, it appears that since the 1996 CB concentration was mapped, wells 1 and 2 (SS003RW111 and SS003RW112, respectively) of the recovery system have reduced the concentration of CB on the north side of the model to less than 1 µg/L (CH2M HILL, 1998g). Overall, the lateral extent of the CB distribution in the S-1 area has been significantly reduced.

2.6.2 SS003 (S-1) Sump Area and Smear Zone SVE

As recommended in the FFS for Site S-1, soils were excavated at the sump area and disposed offsite. At the smear zone, a dual phase groundwater extraction system and SVE were installed.

2.6.3 KY028 (1100 Area) Groundwater Recovery System

The KY028 system is located on the western side of the flight line and makes up a large part of the 1100 Area WMA. About 80,000 gallons of JP-4 jet fuel were released at this site. PCE, TCE, DCE, VC, benzene, nickel, and chromium were detected above maximum contaminant levels (MCLs) in the groundwater at or near the system. A groundwater treatment and reinjection system and SVE system operated from 1992 to 1998 to address impacted groundwater and soil, respectively.

TNRCC granted site closure on July 9, 1998. However, chlorinated solvents in this area will still be addressed as part of SS050.

2.6.4 KY029 (1500 Area) Bio-Venting System

A soil bio-venting field of 6 wells treated the affected soils in the immediate area of the 1,000-gallon jet fuel spill site. The soil bio-venting system was initiated in 1992 and concluded in January 2001. A request for NFA was approved by the TNRCC in December 2001 for this site, with a request for a final site closure document to be sent before February 2002.

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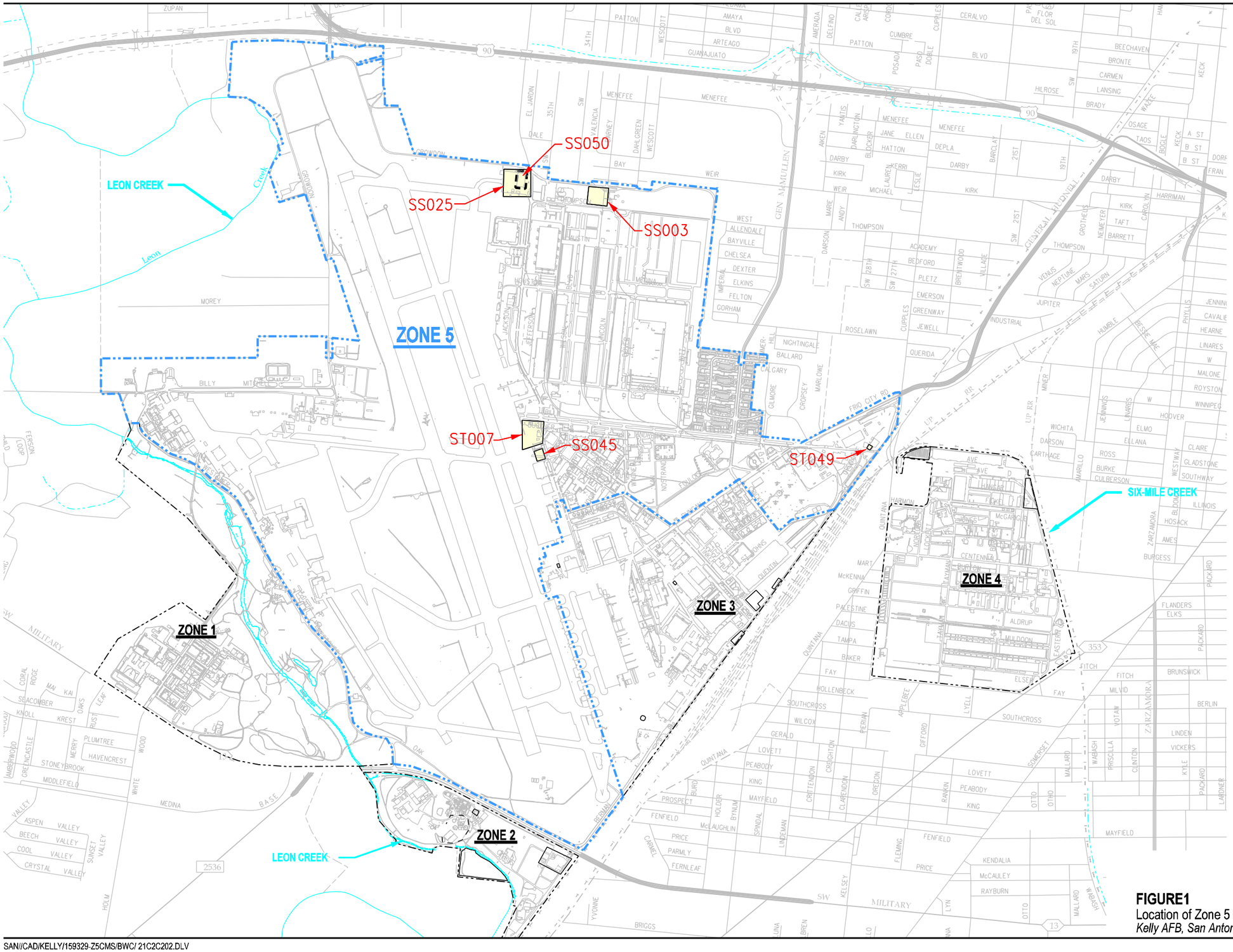


LEGEND

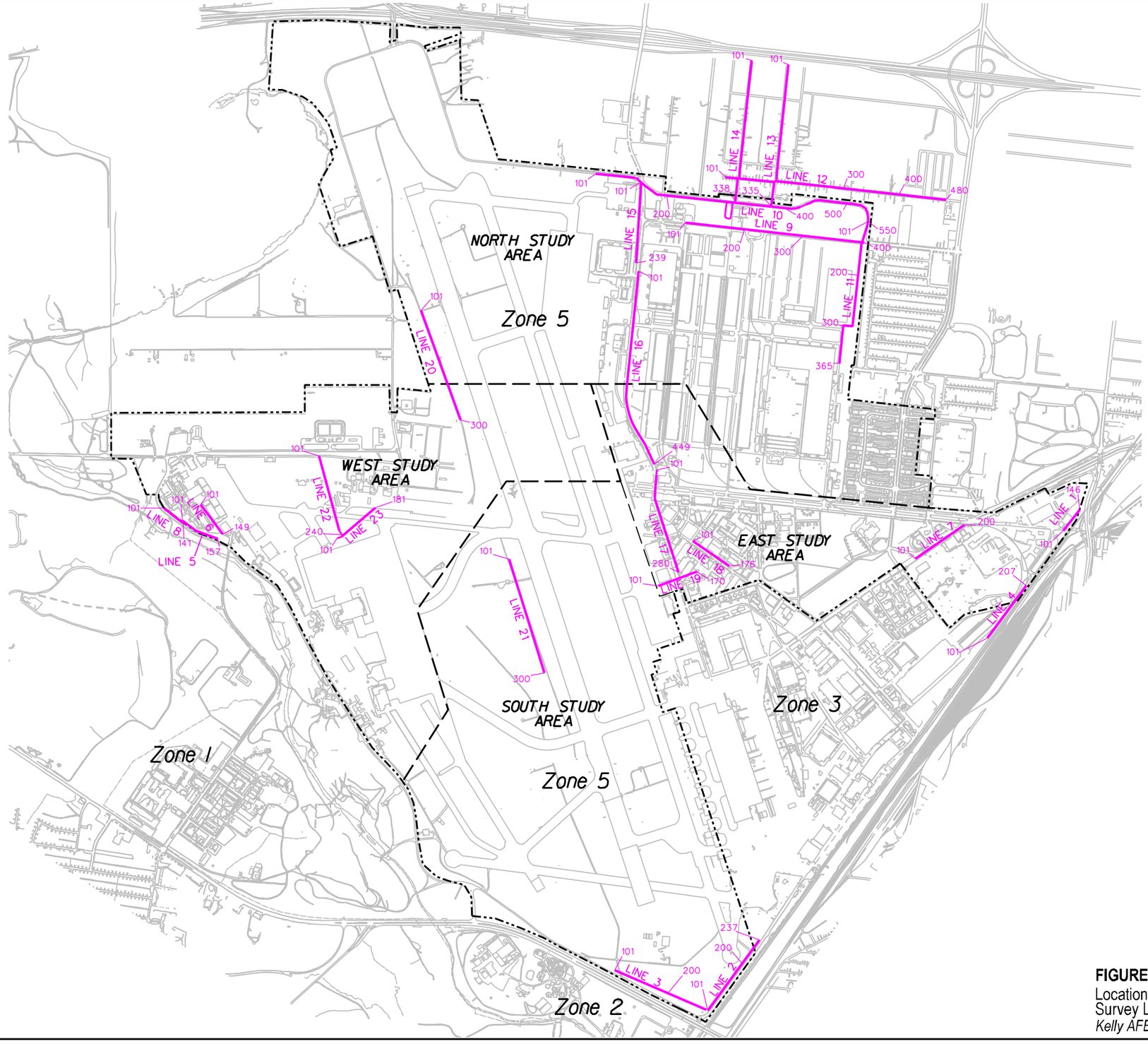
Zone 5 Boundary

Areas of suspected or potential areas for surface and shallow subsurface soil contamination. (0-6' BLS)

IRP Sites — WMS 10

FIGURE1
Location of Zone 5 IRP Sites
Kelly AFB, San Antonio, Texas

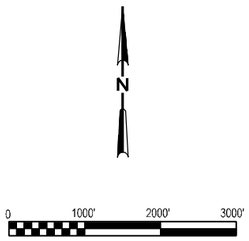
CH2MHILL



LEGEND:

- Seismic Line
- Seismic Station Number 207
- Seismic Line Number LINE 7
- Well Surveyed for Downhole Seismic Velocity
- Zone 5 Boundary
- Study Area Boundary

FIGURE 2-3
Location Map for Seismic Reflection Survey Lines and Wells
Kelly AFB, San Antonio, Texas



LEGEND:

Navarro Group Surface Elevation Contour (feet NGVD) 650

Zone 5 Boundary

NOTES:

1. Elevations are in feet above National Geodetic Vertical Datum (NGVD).
2. Contour interval is 5 feet.
3. Contours indicate approximate average NGVD elevations and are estimates of spatial variations throughout the site.

FIGURE 2-4
Surface Topography for Top of Navarro Group
Kelly AFB, San Antonio, Texas

CH2MHILL

TABLE 2.1
WMA, IRP, and AOC Sites in Zone 5
Kelly AFB, San Antonio, Texas

WIMS Site ID	IRP Site/ Building No.	Description	Applicable Regulatory Program	TNRCC Closure Actions
SS003	S-1	A WMA; former storage area; interim onsite groundwater recovery system installed in 1995.	Permit and Compliance Plan for soil and groundwater	None to date
ST007	S-5	Underground storage tank site; 18 tanks removed in July 1993	Soil and groundwater will be addressed under 30 TAC 334	Letter of closure received on February 24, 1993; site referred to I&HW Division (LPST No. 107368)
SS045	S-10	Underground storage tank site; 3 ASTs were removed from this site	Permit and Compliance Plan for groundwater	A closure report has been submitted for site soils
SS025	IS-1	Former solvent still	IRP RI/FS process for soil and groundwater	Closure of former solvent still approved by TNRCC
ST0049	Building 38	Underground storage tank facility; 4 tanks removed in December 1992	Soil and groundwater will be addressed under 30 TAC 334	PST-RPR waiting on LSA and RA from Kelly. Closure report submitted to TNRCC under PST on June 1994. LPST site transferred to I&HW (LPST No. 102039). All tanks have been removed.
SS050	OT-50	Originally consisted of groundwater contamination that may be associated with Site SS025 (IS-1). The WIMS designation has since been expanded to include all groundwater in Zone 5.	Permit and Compliance Plan for groundwater	None to date
KY028	1100 Area	An AOC; jet fuel spill site; KY028 groundwater treatment/reinjection system in place since 1992	Soils will be addressed under separate compliance plan site closure 30 TAC 334 for groundwater	Site closed in 1998.
KY029	1500 Area	AN AOC; Jet fuel spill site in 1991	Soils will be addressed under separate compliance plan site closure; 30 TAC 334 for groundwater	Closure report submitted.

WIMS = work information management system

TABLE 2.2
Summary of Previous SS003 (S-1) Investigations
Kelly AFB, San Antonio, Texas

Study	Date of Study	Soil Borings	Soil Samples	Depth of Soil Sampling (feet)	Parameters Analyzed	Comments
1994: Site S-1 RI (Halliburton NUS, 1994a)	1989 to 1991	20	36	Surface to 37	VOCs, SVOCs, metals, inorganics, BNAs, pesticides, TPH	Comprehensive RI for Site SS003 (S-1)
1994: Site S-1 RI (Halliburton NUS, 1994a)	5-89 and 11-90	38	52	Surface to 2	PCBs	Shallow sampling to delineate PCB extent in soil
1996: SAIC Borings (SAIC, 1996, unpublished information)	1996	7	28	Surface to 36	SVOCs, metals, pesticides, PCBs, VOCs	
1997: Building 1592 Supplemental Surface Samples and Borings (CH2M HILL, 1997e)	1997	41	42	Surface to 2	VOCs, SVOCs, PCBs, metals	Surface sampling and borings to support a risk assessment for Building 1592 area
1997 SAIC Borings	1997	3	9	Surface to 31	Metals, SVOCs, PCBs, VOCs	
1997: CH2M HILL Borings (CH2M HILL, 1998c)	9-97	10	30	Surface to 26	Alkalinity, CEC, TPH, sulfates, TOC, metals, SVOCs, VOCs, pesticides, PCBs	Further delineate extent of contamination

BNA = base neutral acid
CEC = Cation exchange capacity
SVOC = Semivolatile organic compound
VOC = Volatile organic compound
TPH = Total petroleum hydrocarbons
PCB = Polychlorinated biphenyls
RI = Remedial Investigation

TABLE 2.3
Summary of Previous Zone 5 Investigations and Studies
Kelly AFB, San Antonio, Texas

Site	Action	Purpose	Reference
ST049 (B38)	Site assessment, PST inspection and removal	Assess levels of contamination in the groundwater and vadose zone soils at the site. Four PSTs were removed.	Parsons ES, 1995
ST005 (S-5)	Phase I and Phase II site investigations	Investigate the nature and extent of groundwater/soil contamination. Phase I consisted of the initial site investigation; Phase II consisted of the complete RI.	NUS, 1991; HNUS, 1992
ST005 (S-5)	Closure report	Provide documentation in support of closure in accordance with TNRCC requirements.	Raba-Kistner, 1994a
SS045 (S-10)	Site investigations (associated with the phased activity for site ST005 [S-5])	Investigate the nature and extent of groundwater/soil contamination.	HNUS, 1992; Raba-Kistner, 1994b
SS025 (IS-1)	Phase II IRP investigation; RI reports	Investigate the nature and extent of groundwater/soil contamination. Surface soil samples were collected and analyzed during Phase II; nine soil borings and four monitoring wells were installed and sampled during the RI.	SWL, 1992a
SS025 (IS-1)	Baseline risk assessment	Evaluate risk associated with shallow and surface soils.	SWL, 1992c
SS050 (OT 50)	Site investigations (originally associated with the phased activity for site SS025 [IS-1], now includes all groundwater in Zone 5)	Investigate the nature and extent of groundwater/soil contamination.	SWL, 1992c
KY028 (1100 Area)	Site chronology	Chronicle of events from 1988 to 1991.	IT, 1992
KY028 (1100 Area)	Site assessment	Characterize the site and determine the extent of contamination. Soil borings and monitoring wells have been installed and sampled.	USACE, 1991
KY028 (1100 Area)	Closure report	Provide documentation in support of closure in accordance with TNRCC Plan A.	SAIC, 1997
KY029 (1500 Area)	Site assessment	Characterize the site and determine the extent of contamination. Investigations include: 1) soil vapor survey (1990), 2) soil boring investigation (1991), and 3) monitoring well installation and sampling (1992).	SWL, 1991 SWL, 1992d,
B1592	Baseline risk assessment	Evaluate risk associated with soils.	NUS, 1997

RI = Remedial Investigation
TNRCC = Texas Natural Resources Conservation Commission

TABLE 2.4
Building Numbers of Petroleum Storage Tank Sites in Zone 5
Kelly AFB, San Antonio, Texas

Building	Status	Date of Status
811	Closed	1996
823	Closed	1998
830	Closed	1995
880	Closed	1998
894	Closed	1994
919	Closed	1999
946	Closed	1997
956	Removed	1994; Closure pending documentation of well plugging by Lackland AFB
960	Closed	1994
966	Closed	1995
967	Closed	1996
980	Removal in progress	Lackland AFB
1443	Closed	1998
38	Removed	2001; Closure in progress
98	Removed	2001; Risk-based closure scheduled
1160	Closed	1998
1161	Closed	1998
1408	Closed	1998
1417	Closed	1996
1419	Closed	1997
1469	Closed	1998
1484	Closed	1991
1493	Closed	1998
1501	Closed	1998
1504	Closed	1998
1512	Removed	2000; Report submitted; approval pending
1536	Removed	1995; Closure report to be re-submitted
1537	Closed	1997
1544	Closed	1996
1568	Closed	1996
1588	Closed	1996
1592	Removed	2001; Report submitted; approval pending
1593	Removed	2001; Report submitted; approval pending
1594	Removed	2001; Report submitted; approval pending
1610	Closed	1992
1614	Closed	1998
1618	Closed	1993
1625	Closed	1998
1650	Closed	1998
1655	Removed	1994; Closure report to be re-submitted
1674	Removed	1992; Closure report to be re-submitted
1679	Closure approved	1998
1680	Closure approved	1998
1740	Closure approved	1992

TABLE 2.5
Soil Vapor/Mini-Well Survey for 149th/Westover Road
Kelly AFB, San Antonio, Texas

IRPIMS No.	Date Sampled	Northing	Easting	Elevation (msl)	Type	Depth (ft)
SS050SV347	6/4/97	563706.4	2128399.4	651.23	MW	18
SS050SV355	6/4/97	563654.8	2128332.4	643.41	MW	22
SS050SV348	6/4/97	563738.4	2128303.7	646.27	MW	20
SS050SV354	6/4/97	563687.1	2128239.4	643.96	MW	21
SS050SV349	6/4/97	563770.6	2128206.8	647.10	MW	19
SS050SV353	6/4/97	563726.0	2128138.6	644.64	MW	16
SS050SV351	6/4/97	563806.0	2128107.9	647.89	MW	13
SS050SV352	6/4/97	563766.3	2128038.8	645.82	MW	21
SS050SV350	6/4/97	563844.6	2128013.6	647.25	MW	17

Notes:
1. Mini-wells (MW) only were installed
2. ND indicates "not detected" for all constituents sampled.
3. Water analyses were conducted for volatile halogenated and aromatic hydrocarbons and TPH and include 1,1-DCE, 1,2 DCE (total), TCE, PCE, 1,1,1-trichloroethane, VC, benzene, toluene, ethylbenzene, total xylenes, and TPH.

TABLE 2.6
Other Areas Under Evaluation In Zone 5
Kelly AFB, San Antonio, Texas

FAC	Site Description	Type	SWMU No.	Additional Investigation	Status/Next Document
50	OWS	N/A	N/A	N	Closure Approved
70	OWS	N/A	N/A	N	Closure Approved
894	OWS	NOR/RFA/CP	72/111	N	Closure Approved
894	CSA	NOR/RFA/CP	051/060	Y	RFA
966	OWS/USTs	NOR/RFA/CP	045/092,093,115	N	Closure Approved
1418	OWS	CP	N/A	N	Removed/Closure Report
1418	Lift Station	EBS	N/A	N	Removed/Closure Report
1420	CSA	NOR	77	N	NFA Closure Report
1501	AST	NOR	60	N	NFA Closure Report
1501	OWS	RFA/CP	119	N	Removed/Closure Pending
1501	Wash Rack	EBS	N/A	N	NFA Closure Approved
1516	OWS	RFA/CP	120	N	Closure Approved
1519	OWS	EBS	N/A	N	Removed/Closure Pending
1519	Wash Rack	EBS	N/A	N	NFA Closure Approved
1575	USTs	EBS	N/A	N	NFA Closure Pending
1586	AST	NOR/RFA	046/096	N	Active/Closure Report
1586	OWS	NOR/RFA	055/121	Y	Active/Work Plan
1592	USTs	RFA/CP	97,98,99	N	Removed/Closure Pending
1655	UST	NOR/RFA	047/102	N	Removed/Closure Pending
1655	UST	NOR/RFA	047/103	N	Removed/Closure Pending
1655	Boilers	NOR	38	N	NFA/Closure Approved

TABLE 2.7
Summary of Interim Remedial Actions Status
Kelly AFB, San Antonio, Texas

WIMS Site ID (IRP Site Alias)	Action	Purpose	Status
SS003 (S-1)	Groundwater treatment.	Recover and treat contaminated groundwater.	Soil removed in November 1999 and dual-phase operation began in July 2001.
SS003 (S-1)	Soil excavation at Sump Area and Dual phase groundwater extraction and SVE.	Address soil contamination and close under RRS #3.	Completed the soil removal, and the SVE is currently in operation.
KY028 (1100 Area)	Groundwater treatment and reinjection/SVE.	Recover, treat, and reinject groundwater; collect/treat vadose zone gases.	Closure approved.
KY029 (1500 Area)	Soil bio-venting.	Supply oxygen for biological breakdown of TPH.	System closed.

SVE = soil vapor extraction

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SECTION 3.0

Groundwater Characterization

Environmental characterization activities at Kelly AFB have resulted in numerous types of data from a variety of sources. Contaminants of concern (COCs) for soil in Zone 5 are present only at site SS003 (S-1). They consist of CB and its co-contaminants, 1,2-DCB and 1,4-DCB, TCE, PCE, benzene, and PCBs. The principal Zone 5 source site is SS003 (S-1). An interim action consisting of removal and disposal of contaminated soil at the former sump area and SVE in conjunction with groundwater recovery and treatment at the "smear zone" was implemented in July 2001. This interim action represents the final action at Site S-1. Therefore, no other soil evaluation is needed in this CMS. This section summarizes the Zone 5 information for groundwater. The source for most of the information presented in this section is the Kelly AFB IRP Zone 5 RI Report (CH2M HILL, 1999).

3.1 Site Subsurface and Hydrogeologic Conditions

The basewide hydrogeologic setting has been characterized in depth in the NUS Corporation Basewide Hydrogeologic Assessment, Section 4 (NUS, 1989). Findings of this report are summarized below to provide a framework for the discussion of the Zone 5 geology.

3.1.1 General Setting

A thin and complex water table aquifer exists throughout Kelly AFB, bounded both laterally and vertically at its base by the Navarro Group clay aquitard. The saturated alluvial sediments overlying the Navarro Group are defined as the alluvial aquifer. These alluvial sediments generally fine upward from coarse basal gravel to silt, clay, and fill material. The fining upward is attributable to depositional environments that range from a migrating braided stream system to a meandering stream system. The basal gravel and clayey gravel lithofacies are widespread and are the most common water-bearing units.

The topography of the surface of the Navarro Group has a strong influence on groundwater flow (Figure 2.4). Where the elevation of the surface is greater than the water table elevation, the alluvial aquifer is dry. These areas serve as lateral boundaries affecting groundwater flow (NUS, 1989).

NUS (1989) divided the shallow stratigraphy into 11 units, which included two types of manmade fill material; eight lithofacies, defined as distinct, lateral subdivisions of a stratigraphic unit, distinguished by lithology; and the upper Navarro Group. Not all of the lithofacies occur throughout Kelly AFB, and lateral and vertical discontinuities in the lithofacies are common. An idealized stratigraphic sequence of these lithofacies is shown in Figure 3.1 and was adapted from NUS (1989).

Landfill and fill materials are not considered lithofacies because they have been disturbed by manmade activity. Both landfill and fill material have been identified on base and are identified separately when possible. A generalized description of the fill is that the

materials consists of tan, dry, hard limestone gravel with caliche, roots, and grass. At some locations the fill may be the clay type, which consists of black clay with isolated limestone gravel and some caliche.

The black clay lithofacies is an organic-rich clay with variable amounts of gravel and trace amounts of silt, caliche, and fine sand. It grades into the brown clay lithofacies, which is distinguished by more caliche nodules, silt and sand, and occasional thin gravel stringers.

The silt and sand lithofacies, which may also contain some clay, silt, and gravel, are not as laterally extensive as the other lithofacies. The thin sand unit sometimes overlies the Navarro Group directly, and, if present, is the most transmissive water-bearing unit.

The clayey gravel and gravel lithofacies are typically brown-gray to light tan. The clayey gravel is often sandy and loosely consolidated. The clasts in the gravel facies are often subrounded to angular and poorly sorted. The gravel and clayey gravel lithofacies are transmissive water bearing units.

The areally extensive Navarro clay is a mottled orange-brown, blue-gray to green-gray, stiff plastic clay with silty partings. Some fine sand layers are present, and caliche may be present in the upper 6 ft.

Caliche, a diagenetic calcium carbonate cement, is found as nodules or thin coatings on gravel in the alluvium. In some cases, particularly in borings drilled above local highs in the Navarro Group surface, sections of calichified clay, silt, and gravel were found (NUS, 1989). The presence of calichified material may be significant hydrogeologically because it can impede groundwater flow.

3.1.2 Hydrogeologic Units

The subsurface sediments beneath Zone 5 can be grouped into three main hydrogeologic units. These units consist of a silty clay to clayey silt surficial unit, a clayey gravel to gravel zone, and the Navarro Group. Although the silty clay to clayey silt surficial unit has a low permeability, it allows recharge from precipitation to penetrate the gravel zone. The main water-bearing unit is the clayey gravel to gravel zone, which is the alluvial aquifer at the site. The Navarro Group is a very low permeability confining unit or aquitard. The elevation of the Navarro Group surface influences the thickness of the basal alluvium (clayey gravel and gravel unit) and the saturated thickness (alluvial aquifer). Table 3.1 shows the range in elevation of the Navarro Group and the range in thickness of the shallow alluvial aquifer.

Because of the undulating surface of the Navarro Group, the aquifer thickness varies throughout Zone 5. The saturated thickness is very thin to non-existent in the northwest part of the north area of Zone 5 where the Navarro Group is near the surface, and generally thickens away from this area. The saturated thickness thins from west to east in the south due to the abrupt rise in the Navarro Group surface. In the west, the saturated thickness thins from northeast to southwest. The saturated thickness generally thins from east to west in the east. Channel features are evident in some areas. Cross sections of each study area of Zone 5 can be found in the Zone 5 RI report (CH2M HILL, 1999).

3.1.3 Hydrogeologic Framework

Groundwater in Zone 5 originates primarily as local recharge of precipitation. A minor component of flow may enter along the northern boundary of Zone 5 near the potentiometric high. Groundwater flow occurs predominantly in the clayey gravel to gravel zone, which was generally identified in most of the Zone 5 RI soil boring logs. The clayey gravel to gravel zone ranges in thickness from 1 ft to 32 ft, but generally extends 10 ft to 20 ft above the upper Navarro Group surface. Semi-confined conditions exist in Zone 5 along the boundary with Zone 3, where the clayey gravel to gravel zone is less than 10 ft thick.

Four properties are commonly used to describe the hydrogeologic framework in which groundwater flows: hydraulic gradient, hydraulic conductivity, effective porosity, and groundwater velocity. Each of these properties are discussed for the four study areas in the Zone 5 RI report (CH2M HILL, 1999) and are summarized in Table 3.2.

Hydraulic conductivity values for the alluvial aquifer in Zone 5 range from about 0.2 ft/day to over 400 ft/day, based on slug test results (CH2M HILL, 1999). Hydraulic conductivity is highest near the north Zone 5 boundary, east of the potentiometric high, and along the boundary with Zone 2. Hydraulic conductivity values vary widely over relatively short distances, which is consistent with the fluvial sediment in the study area (CH2M HILL, 1999).

The potentiometric surface of the surficial aquifer mimics the surface of the Navarro Group. Figure 3.2 is the potentiometric surface map of Kelly AFB in March 2000. Data in support of the potentiometric figures can be found in the *2000 Basewide Remedial Assessment Report* (CH2M HILL, 2001). Groundwater flow in the area is partly controlled by the elevation of the top of the Navarro Group. General flow directions are shown on Figure 3.2. Groundwater flow is radially away from the potentiometric high. The potentiometric high corresponds to a ridge in the Navarro surface, and may be an area of higher recharge because the coarse, permeable basal units of the alluvium are nearer to land surface. Variations in the groundwater flow patterns are expected from the heterogeneity of the surficial aquifer.

3.1.4 Conceptual Hydrogeologic Model

NUS (1989) developed a conceptual model of the shallow hydrogeologic system at Kelly AFB during a basewide hydrogeologic assessment that also incorporated existing IRP data. This model, which has been revised for the Zone 5 RI study (CH2M HILL, 1999), provides a depositional framework for predicting the distribution of hydrogeologic units, groundwater flow paths, and contaminant migration. The components of the model are the hydrogeologic units, the water table, and the groundwater flow direction. The primary characteristics of the model components are described below and shown in Figure 3.3.

Water from a precipitation event flows through the unsaturated clays to silts and gravel and percolates to recharge the underlying alluvial aquifer. The infiltration amount is dependent on the rate and duration of the precipitation event, the amount of surface runoff and evapotranspiration, and the properties of the soil (e.g., initial water content, hydraulic conductivity, and surface soil conditions). The steady-state infiltration rate is nearly equivalent to the saturated hydraulic conductivity of the soil. Because the estimated

permeabilities of the soils are low, ranging from 10^{-9} to 10^{-6} cm/s (0.01 to 12 in./yr), once saturated, percolation is likely to occur slowly. Some localized zones of higher permeability may exist in the upper 2 to 3 ft of sediments where seasonal dry periods may result in desiccation fractures in the clay. Because an actual recharge value cannot be measured, it has been conservatively estimated to range between 1 and 3 in./yr. However, unpublished water budget studies at Leon Creek estimate that the upper range of recharge may be as high as 5 in./yr.

In addition to infiltration from precipitation on the ground surface, recharge to the groundwater can also occur as a result of exfiltration from sanitary sewers, storm sewers, and water mains. While such recharge sources are not normally considered significant enough to be considered (TBC), the relatively low precipitation infiltration of between 1 and 3 in./yr. together with the relatively thin saturated thickness of shallow groundwater at Kelly AFB, makes consideration of all recharge sources important.

Exfiltration from sanitary sewers is a concern relative to the potential for contributions to the groundwater flow as well as potential sources of contamination (see Section 2.4.5 and Appendix B). Much of the sanitary sewer system was inspected in 1993 with the results documented in the Sanitary Sewer Investigation Report (Metcalf and Eddy, 1994). The sanitary sewers were found to have a high amount of infiltration during wet weather, suggesting a substantial potential for exfiltration. The investigation found many sewers cracked, misaligned, obstructed, or having low points where sewage collects. Sewage exfiltrating through cracks would encounter relatively permeable pipe bedding backfill placed in the original trench excavated for the pipe. Because the surrounding soils are low permeability clays and silty clays, the sewage would spread laterally downslope in the trench and slowly infiltrate through the clay and eventually to the groundwater. While the exfiltration does not contribute significantly to groundwater flow, it could add contaminants to groundwater depending on the concentrations in sewage[1].

Zone 5 stratigraphic data indicate that the alluvial aquifer consists of a basal gravel and sand sequence that fines upward to silts and clays. The channel forms and interfingering lateral relationships of these lithofacies are consistent with alluvial fan depositional patterns resulting from migrating streams. The basal gravel and clayey gravel hydrogeologic unit is laterally extensive and is the most common water-bearing unit in Zone 5. The clay hydrogeologic unit forms flow barriers that locally divert groundwater flow.

The upper Navarro surface is a natural barrier to the downward migration of alluvial groundwater and represents the lower boundary of the aquifer system. All subsurface data to date suggest that the Navarro barrier has not been hydrogeologically affected by major Balcones faults. Lateral aquifer boundaries are defined by areas where the Navarro clay emerges above the water table in the northern portion of Zone 5. Some areas of the northern part of Zone 5 are dry for some portions of the year.

Groundwater flow directions and hydraulic gradients appear to be radially away from the potentiometric high. The irregular topography of the upper Navarro Group partly controls the groundwater flow at the base of the shallow aquifer throughout Kelly AFB. The

[1] These discharges are historical releases. If contaminants are still entering the groundwater, it is from vadose zone contamination. Large discharges of solvents to the sewers were not necessary to cause the observed groundwater plumes. Rather, low concentration, intermittent sources of only a few pounds per year of solvent would have been sufficient to cause the plumes. This is an important issue relative to the ability to locate and remediate groundwater contaminant plumes and the potential for future occurrence of plumes.

potentiometric trends in this shallow aquifer reflect both the upper Navarro Group and the ground surface topography, which is typical of water table aquifer systems. The saturated thickness ranges from approximately 0 to 30 ft across Zone 5 with the average thickness being less than 10 ft. Groundwater in the gravel unit has a low hydraulic gradient and flow is approximately horizontal.

3.2 Groundwater Contamination

This section discusses the determination of contaminants of potential concern (COPCs), the nature and extent of groundwater contamination underlying Zone 5, and the fate and transport of the COPC. The data set used for this study is from groundwater samples collected by Kelly AFB for three major projects. These on base and off base projects were the BRA project, Zone 5 RI and *Resource Conservation and Recovery Act* (RCRA) quarterly groundwater monitoring. The combined data set is referred to as the Zone 5 CMS data set and contains results for over 104,000 samples and is in an electronic database. A summary of this data is in Appendix F. The frequency of data collection is project specific. Data used for the determinations of COPCs are from BRA investigations in 1996 and 1997 (CH2M HILL, 1997d; 1998b), RI data collected in 1995 (CH2M HILL, 1999), and the RCRA data collected from 1994 to 1997. The site SS003 (S-1) RI data were not available in electronic format (Halliburton NUS, 1994a). In order to include this data in the COPC determination, the maximum value for each COPC was compared to concentrations determined for site SS003 (S-1) RI (CH2M HILL, 1994). The values did not change with this comparison. Data from the March 2000 Basewide Remedial Assessment has also been summarized to show more recent concentrations of COPCs.

3.2.1 Determination of Groundwater Contaminants

The determination of COPCs for Zone 5 was done in a series of steps. The steps to determine the COPCs are outlined below.

1. The analytical groundwater data from the Zone 5 RI , BRA 1996 and 1997 (CH2M HILL, 1997d; 1998b), and SS003 (S-1) quarterly RCRA sampling were combined into one data set.

2. The highest concentration for each constituent was determined.

3. The frequency of detection for all sampled analytes was determined. If more than 5 percent of the sample results were detected, the constituent was retained for further review. Using 5 percent of the sample results detected may result in an underestimate of the COPCs. Because a more thorough examination of all sample results and past practices is provided in the Zone 5 RI report (CH2M HILL, 1999), the COPCs identified in the Zone 5 RI were retained for further review, even if the frequency of detects was less than 5 percent. A number of constituents considered were removed from further review at this point (see following discussion). A summary of steps 1 through 3 is given in Table 3.3.

4. Determine maximum verifiable concentration for the COPC by following the steps outlined below:

a) Review the other values for the COPC in that well and evaluate whether the maximum concentration is reasonable (use an order of magnitude difference between analyses in the same well as the reasonableness criterion).

b) If the maximum concentration in a well is more than an order of magnitude different than any other from that well, review concentration in nearby wells to confirm that a significant change is reasonable; if not reasonable go to the next highest concentration for that COPC and repeat steps a and b.

c) If there is a significant (order of magnitude) change in a COPC's concentration in a well between 1995 and 1997, evaluate whether the change is reasonable; i.e. review nearby wells for a similar increase.

Some constituents passed the 5 percent detect screen but were eliminated from further review. Ten constituents were eliminated because they are commonly used as analytical standard surrogates for the purpose of calibrating the analytical instrument. These constituents, 1,2-Dichloroethane-D4, 1-Bromo-4-Fluorobenzene (4-Bromofluorobenzene), 2,4,6-Tribromophenol, 2-Fluorobiphenyl, 2-Fluorophenol, Dibromofluoromethane, Nitrobenzene-D5, Phenol-D5, Terphenyl-D14, and Toluene-D8, were dropped at step 2 from further COC consideration. Three constituents were dropped for different reasons: Calcium was dropped because it is considered an essential nutrient, and bis(2-ethylhexyl) phthalate and Di-N-Butyl Phthalate were dropped because they are common laboratory contaminants. Arsenic was dropped from COPC consideration as it did not exceed criteria. One constituent, p,p'- dichlorodiphenyltrichloroethane (DDT), previously identified as a COPCs was removed from further consideration because it was not detected in any of the collected samples.

Barium, iron, lead, nickel, zinc, and chromium are identified as COPCs. These constituents have characteristics that may be pertinent to remedial activities and are therefore discussed in Subsection 3.2.1.1.

Performing these described steps for the Zone 5 CMS data set and then eliminating the constituents described above resulted in 35 COPCs. The COPCs with their maximum verifiable concentration are listed in Table 3.4.

3.2.1.1 Metals Data Evaluation

This section summarizes the approach and results of the total metals data evaluation for the groundwater of Zone 5. The Zone 5 RI indicated that concentration of total metals in groundwater exceed their respective chemical-specific evaluation criteria (CH2M HILL, 1999). The historical analytical data were evaluated to determine where the criteria for metals were exceeded and the data is representative of groundwater concentrations or is an artifact of sampling methods or well corrosion. Ultimately this evaluation will be used in determining the areas that need TBC in the development of remedial alternatives in this CMS report.

The majority of the wells used for groundwater monitoring in Zone 5 are constructed with stainless-steel screens. Studies recently conducted as part of the 1997 BRA have recommended that elevated levels of nickel and chromium in groundwater samples collected from stainless steel wells be carefully evaluated, because the well material could be the source (CH2M HILL, 1998b). Other studies have found elevated inorganics in

monitoring well samples as a result of corrosion. In particular, a study by Oakely and Korte (1996) found corrosion of stainless steel well screens contributing chromium and nickel. Based on the geochemistry of their site, they suggest that chromium released from the well screen would precipitate, while nickel would remain dissolved. Thus, sample collection methods could also result in elevated nickel and chromium concentrations. Recent research has shown that insertion of sampling devices such as bailers, and subsequent rapid sampling, results in the collection of particulate matter that is not representative of water quality in the aquifer (Oakley and Korte, 1996). Soil particles often have several orders of magnitude greater concentrations of metals than does the groundwater in contact with the soil. The heavily concentrated metals in the suspended soil of the groundwater sample are solubilized because of sample acid preservation. This results in unrepresentative sample concentrations.

A nickel-chromium study was conducted as part of the 1997 BRA (CH2M HILL, 1998b), to evaluate whether monitoring well material (specifically stainless steel screens) and/or sampling methods are possible sources of nickel or chromium in groundwater. Five monitoring wells across the base, that historically have had groundwater samples with high levels of nickel and chromium, were used in the study. The results indicated that the stainless steel well screens are the likely source of nickel and chromium. Consistent with the Oakely and Korte findings, the majority of the nickel measured in the wells was dissolved and the chromium resulted from particulates in the sample. However, no relationship between turbidity and the chromium detected was indicated, suggesting that although the chromium is related to particulates, it is not the result of sediment being pulled from the aquifer matrix. Nickel concentrations were found to decrease exponentially with increased purge volumes indicating that the source of the nickel is in the vicinity of the well. Based on the results of the study, the nickel and chromium data were examined to determine if the well screen should be considered the potential source of both metals.

Methodology for Metals Evaluation. The analytical results for total metals were evaluated in the risk assessment process to determine the COPCs. The screening process identified eight metals as COPCs with maximum concentrations exceeding their respective groundwater standard (Table 3.5).

The following methodology was used to evaluate the analytical data for the eight metals:

1. Analytical results for the six metals in groundwater were compared with the appropriate standard to identify the potentially impacted well locations.

2. Analytical data from different sampling events, where available, were examined to determine if the metal concentrations for the potentially impacted well consistently exceeded its respective criteria or if it was a one time occurrence.

3. The well construction and groundwater field sampling logs were examined to determine if the elevated metal concentrations could be attributed to well construction or turbidity and not aquifer contamination.

4. Analytical results were evaluated to determine if concentration of other metals indicative of steel corrosion (i.e., chromium, copper, iron, lead, manganese, nickel, and zinc) were also elevated. Analytical results of metals were also evaluated to determine if

a wide suite of inorganics were elevated and suggestive of sample turbidity as the source of elevated metals.

5. Analytical results of inorganics as well as indicators of the redox conditions of the groundwater were evaluated to determine if metals were mobilized as a result of reducing conditions.

Evaluation Results. Groundwater samples from 57 monitoring wells contained concentrations of arsenic, barium, chromium, cobalt, iron, lead, nickel, or vanadium exceeding its respective standard.

Results for each monitoring well were examined to determine if the reported concentrations consistently exceeded a standard or if the exceedance was a one time occurrence. If the standard was exceeded only once over the monitoring period and was widely different than other results for the same well, the exceedance could be considered anomalous and not indicative of groundwater contamination.

Data for multiple sampling events consisting of at least one sample in 1995, 1996, and 1997 were available for 47 of the 57 monitoring wells exceeding the criteria for metals. Examination of data from the individual monitoring well data found concentrations inconsistent and commonly varied an order of magnitude between sampling rounds. In nearly half of the 47 wells, concentrations exceeded the standard in only one sample over the three year period (Table 3.6). At these locations, the frequency of detection and the lack of consistency between rounds indicate that elevated concentrations are not representative of the contaminants in the aquifer. At 20 wells, evaluation of data found that the exceedances of standards was related to well corrosion or suspended solids present in the sample. Resampling of 10 wells where more than one sample exceeded criteria for either chromium or nickel has been performed where the data were insufficient to determine the representativeness of the data. Sampling at successive intervals during well purging (1, 3, and 10 well volumes) was performed to determine whether the source of the elevated chromium and nickel is well corrosion. The results indicated that the well screens might be adding to some metal result concentrations.

A summary of the data evaluation and whether a well location should be considered in the CMS or requires additional information is presented in Table 3.6. General observations of data for the six metals are discussed below.

Arsenic. The standard for arsenic (50 μg/L) was exceeded in 13 monitoring wells. Based on the frequency that the standard was exceeded and the consistency of the data between sampling rounds, the elevated arsenic concentrations at two of the wells were considered anomalous and not indicative of a potential groundwater problem.

In the remaining 11 wells, the arsenic is believed to be representative of groundwater concentrations. The elevated arsenic concentrations were generally associated with elevated concentrations of barium , manganese, and possibly iron. The arsenic concentrations did not appear to be related to elevated concentrations of chromium or nickel. The data indicate that the arsenic is present as a result of reducing conditions associated with groundwater contamination related to the spills in the East Area and the CB plume in the North Area.

Barium. Barium concentrations in ST007MW054 exceeded the standard (2,000 µg/L) in two of the three sampling events. Barium concentrations ranged from 1,930 to 2,640 µg/L. The barium appeared to be correlated to elevated concentrations of manganese. The manganese concentration at this location ranged from 2,430 to 2,510 µg/L and the arsenic concentration ranged from 47.4 to 77 µg/L. The elevated barium concentration is believed to be representative of the groundwater concentrations at this location and may be related to SS045 (S-10) spill area.

Chromium. The standard for chromium (100 µg/L) was exceed in 26 of the monitoring wells with a maximum concentration of 1,240 µg/L. In 23 of the wells, nickel concentrations also exceeded its standard. The elevated chromium does not appear to be correlated with consistently high concentrations of manganese, zinc or copper.

The chromium-nickel study conducted as part of the 1997 BRA indicated that the potential source of the elevated levels of chromium and nickel may be attributed to the stainless steel well screens. The frequency of detection and variability of the chromium concentrations between sampling rounds indicate chromium concentrations may be related to sampling methods or the well construction and not groundwater contamination. See Table 3.7 for discussion of chromium exceedances for each well.

Iron. The iron data were limited to the 1997 BRA sampling event (CH2M HILL, 1998b). The standard for iron (30,700 µg/L) was exceeded at one location, SS050MW175 with a concentration of 341,100 µg/L. The groundwater sample also contained elevated levels of chromium, copper nickel, manganese, and zinc. Based on these results and the sampling log, the source for the elevated iron could be attributed to the stainless steel well screen or from the action of iron reducing bacteria which converted the insoluble ferric iron to soluble ferrous iron.

Lead. Lead concentrations exceeded the standard (15 µg/L) at six locations. Based on the frequency that the standard was exceeded and the inconsistency of the data between sampling rounds, the lead concentrations at three of the wells were considered anomalous and not indicative of a potential groundwater problem. In the remaining wells, elevated lead values appeared to be associated with elevated concentrations of arsenic, barium, and manganese. The data indicate that the lead is present in reducing conditions associated with groundwater contamination related to the spills in the East Area and the VOC plume in the North Area.

Nickel. The nickel standard was exceeded in 37 of the monitoring wells with a maximum concentration of 5,610 µg/L. In 23 of the wells, the standard for chromium was also exceeded.

The 1997 BRA chromium-nickel study indicated that the potential source of the elevated levels of chromium and nickel may be attributed to the stainless steel well screens (CH2M HILL, 1998b). The frequency of detection, variability of nickel concentrations between sampling rounds and the records of the sampling were used to evaluate the nickel

results. Elevated nickel concentrations in nine wells were thought to be related to sampling methods or the well construction and not groundwater contamination.

The nickel concentrations in five of the wells appeared to be relatively consistent over time. At these locations, the elevated nickel concentrations do not appear to correlate to higher levels of the other metals. Additional sampling using increased purged volumes was conducted at these wells to determine if the stainless steel well screens are the source of nickel. The results concluded that stainless steel well screens are a source of the nickel.

3.2.1.2 Contaminants of Concern

The COCs were determined by comparing the maximum verifiable value to a risk value. This effort is discussed and summarized in Section 3.3. The final list of COCs are the same as that determined in the Zone 5 RI with the addition of cis-1,2-dichloroethene. The COCs are: 1,1-DCE, arsenic, benzene, CB, PCE, TCE, total xylenes, and cis-1,2-DCE.

3.2.2 Nature and Extent of Groundwater Contamination

The nature and extent of groundwater contamination for the COCs are summarized in the following paragraphs. The extent discussion is based on the plume maps. The plume maps were constructed using the 2000 Annual Report BRA data (CH2M HILL 2001). Both the historical (RI, 1996 and 1997) data and the April-June 2000 results are discussed in the following paragraph to provide both the historical levels of contamination and to show the more recent contaminant reductions seen in the March 2000 data set.

Arsenic distribution in the groundwater is shown in Figure 3.4. The standard for arsenic is 50 µg/L. Arsenic historically has been present above the standard at three locations, in the north near site SS003 (S-1), in the east at one well at the highest observed concentration of 152 µg /L using 1997 BRA data, and in the south. Arsenic was observed in a 1995 data set (Zone 5 RI data set, CH2M HILL, 1997a) in the west area of Zone 5 but was not observed in later data collections for the same area or the detected values were below the standard. The maximum verifiable concentration of 85.6 µg/L was observed at well SS003MW110 (north area of Zone 5) during the June 1996 sampling event. The maximum detection of arsenic from the April-June 2000 data set is 65 µg /L at SS050MW357.

The chlorinated solvents PCE, TCE, and DCE are the most widespread contaminants in Zone 5. The highest concentration of TCE is found in the northern section of Zone 5, where concentrations of over 1,000 µg/L are observed. Concentrations have decreased from the 1997 data set. The distribution of TCE is shown in Figure 3.5. The standard for TCE is 5 µg/L. Off base, to the north of Zone 5, concentrations are over 10 µg/L. Other defined areas of TCE plumes are located in the west, central, and southern areas of Zone 5. The maximum verifiable concentration of 1,200 µg/L was observed at well SS050MW118 (north area of Zone 5) in June 1997. In the April-June 2000 data set, the maximum concentration of TCE was 653 ug/L at SS050MW470.

The highest concentrations of PCE are found in the south area of Zone 5 and off base to the north. The PCE distribution is shown in Figure 3.6. Off base PCE contamination in groundwater is not addressed further in this CMS report. The standard for PCE is 5 µg/L. The PCE plume in the south has a low concentration level adjacent to high areas. This feature may be due in part to values representing different times. The maximum verifiable

concentration of 4,200 µg/L was observed at well ST007MW053 (west area of Zone 5) in June 1996. The maximum detection of PCE from the April-June 2000 data set was 1,230 ug/L at ST007MW053.

The DCE distribution is represented by the total 1,2-DCE plume map. The total 1,2-DCE distribution is shown in Figure 3.7. Values over the standard are observed for total 1,2-DCE in the north and area of Zone 5. The maximum verifiable concentration for Total s 1,2-DCE of 376 µg/L was observed at well SS050MW470 (north area of Zone 5) in March 2000. The COC, 1,1-DCE, is found above the standard in one well (ST007MW011) in the east part of Zone 5. The maximum verifiable concentration for 1,1-DCE of 81 µg/L was observed at well ST007MW011 (east area of Zone 5) in June 1997. The maximum detection of 1,1-DCE observed in the April-June 2000 data were 6.8 ug/L.

The maximum verifiable concentrations of xylene is 8,200 µg/L, which was observed at well ST0049MW001 (east area of Zone 5) in June 1997. Only three other wells had detections. All values are below the standard of 10,000 µg/L. Xylene was identified as a COC in the Zone 5 RI (CH2M HILL, 1999), and therefore it is considered a COC in this CMS report. Xylene dropped to less than 1 ug/L in the April-June 2000 data.

Benzene, with a standard of 5 µg/L and CB with a standard of 100 µg/L are both found at high concentrations in the north part of Zone 5. The distribution of benzene and CB are shown in Figures 3.8 and 3.9. CB is also detected in one well in the west part of Zone 5. Benzene is also detected at a few wells in the east part of Zone 5. The maximum verifiable concentration for benzene of 2,020 µg/L was observed at well SS003MW121 (north area of Zone 5) in June 1997. The maximum verifiable concentration for CB of 21,000 µg/L was observed at well SS003MW053 (north area of Zone 5) in June 1997. In the April-June 2000 data set, benzene dropped to 12.3 ug/L and chlorobenzene dropped to 277 ug/L.

For the purpose of this CMS, plumes were grouped by location of contamination or, for some constituents, similar chemical properties or characteristics. These plumes were given a letter designation for ease of reference. The plumes are shown on Figure 3.10. Following is a brief description of each plume.

No source of contamination could be identified for any of the groundwater plumes. However, the plume maps for each COC (Figures 3.4 through 3.9) show areas of elevated concentrations of contaminants. The term “source area” is used throughout this report to indicate those areas in which the groundwater exhibits high contaminant concentrations relative to the rest of the plume. “Source area” is the area within which the actual source of contamination was probably located in the past. However, the extent of the actual source was probably significantly smaller than the extent of the “source area.”

3.2.2.1 On and Off Base TCE (Plume A)

This plume includes site SS025 (IRP site IS-1) . The plume is large and dispersed, encompassing most of the North Study Area, and is migrating off base. The western lobe of Plume A is centered off base. The eastern portion of the plume is currently migrating in a northeasterly direction, off base. Plume A COCs include TCE and DCE. TCE levels are as high as 1,200 µg/L and Total DCE levels are as high as 220 µg/L. The source for this plume is believed to be near the high concentration area located on the base just southeast of the site SS025 (IS-1). Although unsaturated zone soil CVOC contaminants adjacent to the

sanitary sewer is currently insufficient to be the source of the plume, it is believed that past releases from the sewers serving the solvent still in Building 1414 were the source. The Plume A source area is characterized by high levels of DCE and TCE. The source area of this plume appears to be located over a high point in the Navarro Group. Groundwater dispersion in the source area is primarily both north and south, with some migration eastward. An IRP Zone 5 FFS for Source Perimeter Control for Plume A was prepared October 2001 (CH2M HILL , 2001).

3.2.2.2 Off Base PCE (Plume B)

The source area and the body of Plume B are located off base, immediately to the north of the Zone 5 boundary. Plume B is distinguished from the other plumes in the immediate vicinity (Plumes A and C) because the primary contaminant of each plume is different and each plume has a different physical source area. Commingling of the contaminants of each plume has been observed in some locations. The mapped concentrations of contaminants within the plume indicate that the plume is migrating to the north/northeast, away from Kelly AFB. The direction of plume migration is consistent with the groundwater flow direction in this area (CH2M HILL, 1998b). Analytical results for groundwater samples collected in this area suggest that the source of the plume is off base and, therefore, not related to operations at Kelly AFB. Remedial alternatives for PCE Plume B are addressed in Section 9 of this CMS report. Plume B COCs include PCE, TCE and DCE. PCE levels have been as high as 2,600 µg/L, TCE levels are as high as 31 µg/L, and Total DCE levels are as high as 25 µg/L. The TCE plume that is comingled with Plume A is being addressed in this CMS. The source area for this PCE plume is estimated to be slightly upgradient of the high concentration area located where PCE levels have approached 2,600 µg/L.

3.2.2.3 Chlorobenzene, Arsenic (Plume C)

This plume includes the contamination plume associated with site SS003 (S-1). The plume is underlying a former waste storage site used for storage of solvents, oils, cleaning compounds, petroleum, and lubricants from the 1960s until 1973. The plume is much smaller than other adjacent plumes. In the past, the plume has migrated to the northeast off base. Recent data indicate that the plume has diminished in size and is now confined to areas on base. Plume C COCs include benzene, CB, cis 1,2-DCE, TCE, and arsenic. Benzene levels have been as high as 2,020 µg/L, CB levels has been as high as 21,000 µg/L, cis 1,2-DCE levels have been as high as 220 µg/L, PCE levels have been as high as 25 µg/L, TCE levels have been as high as 5.5 µg/L, and arsenic levels have been as high as 263 µg/L. An interim measure (groundwater extraction and treatment) to remediate the site is ongoing. As discussed earlier, an additional interim measure has been implemented for site SS003 (S-1) (CH2M HILL, 1997c). An interim action has been implemented for Plume C. The interim included the removal of soil in the vadose zone, groundwater extraction wells at the base boundary and dual phase vapor extraction and recovery wells within the site. The system will remove contaminants from the site and will also supply oxygen to enhance bioremediation. This interim action is the final action at SS003. Therefore, Plume C will not be addressed further in this CMS.

3.2.2.4 1600 Area – TCE, PCE, 1,2-DCE (Plume D)

This plume includes the contamination plume associated with the 1600 Area. Plume D is a combination of at least four different smaller contaminant plumes that do not necessarily

have the same source. The plume is located just east of site ST007 (S-5) and SS045 (S-10) (Plume G). Plume D is migrating in a southeast direction toward Zone 3. Plume D COCs include DCE, PCE, and TCE. Total DCE levels have been as high as 16.5 μg/L, PCE levels have been as high as 4,200 μg/L, and TCE levels have been as high as 240 μg/L. The southern and northern portions of the plume contain TCE, with the PCE located near the center, just east of site SS045 (S-10). BTEX compounds are co-contaminants with PCE at this location. DCE is found in just a few groundwater wells at the south end of the plume.

3.2.2.5 Civil Engineering Motor Pool – Benzene, Arsenic (Plume E)

This plume includes the contamination plume at site ST049 (Building 38 Area) associated with the Civil Engineering Motor Pool. This plume will be remediated under 30 TAC 334 rules and will not be addressed in this CMS.

3.2.2.6 Low Concentration PCE (Plume F)

Plume F is a combination of at least four different smaller contaminant plumes of unknown source(s) and that do not necessarily have the same source. The plume is located just east of the 1600 Area site (Plume D). Plume F COCs include PCE. PCE levels have been as high as 9 μg/L in the northeast portion of the plume, and as low as 5 μg/L in the southeast portion of the plume.

3.2.2.7 ST007 (S-5) Benzene Spill, Arsenic (Plume G)

Plume G includes the contamination plume associated with site ST007 (S-5). Plume G is a combination of at least two different smaller contaminant plumes that do not necessarily have the same source. Groundwater in the vicinity of this site is contaminated with petroleum products; co-contaminants are not known to be present. Monitored natural attenuation of groundwater, the alternative recommended in the FS for this site (Halliburton NUS, 1993), was approved by the TNRCC. On November 19, 1993, the TNRCC approved closure of site ST007 (S-5) under 30 TAC 334 and indicated that no further remedial action is required at this time. The site is now closed (Raba-Kistner, 1994a) and will not be discussed further in this CMS report.

3.2.2.8 Central Runway – TCE, Total 1,2-DCE (Plume H)

This plume is migrating in a southward direction. The plume is located directly underneath the flight line. Plume H COCs include TCE and Total 1,2-DCE. TCE levels have been as high as 40 μg/L, and Total 1,2-DCE levels have been as high as 13 μg/L. The TCE levels have been highest in the northern portion of the plume, while Total 1,2-DCE levels have been highest in the central portion of the plume. Plume H occupies a groundwater low-velocity region, where it is an extension of the Navarro Ridge (HGL, 2000). For further information on Plume H and modeling results, see Appendix G.

3.2.2.9 PCE, TCE, DCE (Plume I)

This plume includes the contamination plume emanating from the area near Building 360. Because the source of Plume I is located in Zone 3, corrective measures for Plume I will be evaluated in the Zone 2 and Zone 3 CMS reports. It will not be discussed further in this CMS.

3.2.2.10 KY028 (1100 Area) PCE, TCE (Plume J)

Plume J includes the contamination plume associated with KY028 (1100 Area). Plume J is a combination of at least two different small contaminant plumes, and is approximately 1,300 ft wide by 1,850 ft long (north/south), and approximately 5 ft thick. The plumes are located underneath KY028 (the 1100 Area) and are migrating southwest. Plume J COCs include PCE and TCE. PCE levels have been as high as 120 µg/L, while TCE levels have been up to 8 µg/L. PCE is predominant throughout the plume, while TCE exists mainly in the southwest corner of the plume. There was an SVE and groundwater recovery system in operation to help remediate contamination from a former fuel spill. The SVE system is no longer in operation. Closure was granted 19 July 1998.

3.2.2.11 West Chlorobenzene (Plume K)

Plume K is defined by detection in a single well. The plume is considered to be small, although its actual size is not known. Plume K is located west of the KY028 (1100 Area) plume (Plume J). Plume K COCs include CB. CB levels have been as high as 440 µg/L. The maximum concentration from the 2000 Annual Sampling event is ____ µg/L. The dimensions of this plume are uncertain because of the limited information on CB in this area. The closest well to this plume is about 1000 ft away and CB was not detected.

3.2.3 Conceptual Fate and Transport Model for Groundwater

This section summarizes the information presented in the Zone 5 RI study (CH2M HILL, 1999) which evaluates the potential fate in the environment of contaminants. The topics discussed in this section are the physical and chemical properties of the aquifer (Table 3.7), physical and chemical properties of the COCs and the fate and transport of these constituents.

The physical and chemical properties of the aquifer affect the transport of the contaminants in groundwater. Table 3.2 summarizes the conditions present in Zone 5 of Kelly AFB. Rainfall at Kelly AFB averages 29.1 in. per year. Zone 5 is relatively flat, which reduces potential runoff. Although an actual recharge value cannot be measured, it has been estimated to range between 1 and 3 in./yr. The low value occurs because evaporation and evapotranspiration at Kelly AFB are greater than the available precipitation and the low permeability of the surface soils. The recharge (infiltration) rate is defined as the volume flux of water flowing through the unsaturated zone per unit of soil surface area. The steady-state infiltration rate is practically equivalent to the saturated hydraulic conductivity of the soil. At Zone 5, the estimated permeabilities of the soils range from 10^{-9} to 10^{-6} cm/s. A conservative infiltration rate estimate of 3 in./yr was used to evaluate contaminant transport. The velocity was calculated based on Darcy's Law, where the flux assumes that flow occurs through the media without regard to solids and pores. Because the flow is only limited to the pore space, the average linear velocity is calculated by dividing the groundwater flux by the effective porosity. The effective porosity, with respect to contaminant transport through saturated or near-saturated clays, can be reasonably estimated based on the moisture content determined according to the geotechnical tests. Thus, the velocity of the infiltrating water (1.25 ft/yr) was calculated by dividing the infiltrating rate (3 in./yr) by the volumetric moisture content (0.20).

The behavior of contaminants in the groundwater is tied to the contaminants' chemical characteristics. Characteristics that influence behavior are partitioning and degradation. The Zone 5 RI report (CH2M HILL 1999, Appendix J) summarizes the basic properties of the contaminants. The chlorinated solvents (PCE, TCE, and DCE) were found in groundwater. PCE and TCE may have differed in use over time or could have been released in different areas. Therefore, correlating these constituents to biodegradation must be done with knowledge of disposal practices. Benzene, CB, and xylenes are also mobile in groundwater and are highly volatile, and biodegrade under aerobic conditions. The metal, arsenic, was also found in the groundwater. Arsenic is persistent (i.e., it does not degrade). Arsenic will precipitate out under the proper oxidizing conditions.

The contaminant transport rates of the COC varies with the constituent and with the differing groundwater flows in Zone 5. The migration rates are presented in detail in the Zone 5 RI (CH2M HILL, 1999). Appendix H presents a summary of the estimated migration rates for selected contaminants in Zone 5. The range of rates is estimated from 10^{-6} to over 4 ft/day.

To assist in this CMS, Hydrogeologic Inc. performed the modeling of COCs to determine their fate and transport under natural conditions. The modeling was accomplished by using Hydrogeolgic's ModFlow– Surface Code. ModFlow– Surface is based on U.S. Geological Survey Modular groundwater flow model, ModFLow. Tables 3.8 and 3.9 provide a summary of the time to reach MCLs for remediation options proposed for Plume A, D, H, and J. This modeling, however, was conducted in November 1999 and therefore did not include the new proposed alternatives for Plume A. The baseline, however, is still the same. Benzene, and Chlorobenzene, in plumes B, C, E, and G were not modeled due to the small size of the current plumes above MCLs. These plumes are relatively small, almost entirely on base, and show very little sign of migration. All these plumes are monitored annually. Arsenic in plumes C and E were not modeled due to the small size of the current plumes above MCL. Appendix G contains the entire Hydrogeologic modeling report. Following is a summary of the results for each plume.

3.3 Summary of Human Health and Ecological Risks

This section summarizes the human health and ecological risks posed by contaminants in Zone 5. This summary consists of two parts: a summary of the results of previous risk assessments conducted for Zone 5 and a qualitative evaluation of potential impacts to these risk characterizations posed by the evaluation of the Zone 5 CMS groundwater data outlined in Section 3.2.

3.3.1 Previous Risk Assessments

Risk assessments for each of the four study areas in Zone 5 (North Study Area, South Study Area, West Study Area, and East Study Area) are presented in the Zone 5 RI report (CH2M HILL, 1999). The following subsections summarize the results of these risk assessments.

3.3.1.1 Exposure Assessment

Potential routes through which human receptors could become exposed to contaminants at Zone 5 were identified. Potential exposures could occur directly within Zone 5 or as a result of contaminant migration to off base receptors. Media of concern are soils and groundwater. Potential receptors include local residents, as well as military and civilian base personnel. Current and future exposure scenarios were evaluated in the risk assessments.

Receptors under current and future exposure scenarios could be exposed to contaminated soils through incidental ingestion, inhalation, and dermal contact. Current receptors (i.e., maintenance workers, groundskeepers) could be exposed through inhalation of volatile constituents from contaminated groundwater during work activities. Future receptors could be exposed to contaminated groundwater via ingestion, dermal contact, and inhalation of volatile contaminants while showering.

Additional exposure routes were considered in the risk assessments but were determined to be insignificant mechanisms for human exposure. These routes included inhalation of volatile emissions from sites within Zone 5 itself, inhalation of volatiles in residential areas as a result of outgassing from groundwater through the soil and into the ambient air, and exposure associated with erosional transport of surficial contaminants (CH2M HILL, 1999).

3.3.1.2 Human Health Risk Characterization

The likelihood of adverse health impacts associated with long-term exposure to contaminants at Zone 5 was evaluated by calculating excess lifetime cancer risks from carcinogens and hazard indices for noncarcinogens. The COPCs evaluated include all detected organic chemicals as well as inorganic chemicals detected at greater than the naturally occurring levels (in soils) and at concentrations exceeding the daily intake for essential nutrient metals. Estimated human intakes were developed for each of the specific exposure routes described in subsection 3.4.1.1. These estimates provide the basis for carcinogenic and noncarcinogenic risk characterization. Exposure and risk estimates were generated using conservative (i.e., health-protective) reasonable maximum exposure and average exposure values. Specific assumptions used for the four areas are presented in the RI report for Zone 5 (CH2M HILL, 1999).

Risks were evaluated for on base and off base residents and for on base workers. Overall, the risk assessments concluded that the most significant risks are associated with potential potable use of contaminated water from the shallow aquifer. Risks from residential use of groundwater are above the levels considered acceptable (i.e., $> 10^{-4}$ to 10^{-6}). However, the recent shallow aquifer study did not reveal any shallow domestic wells in the immediate vicinity of the base that are used for potable supply. No risks to humans from volatilization of constituents in groundwater to ambient outdoor air appear to exist.

No unacceptable risks were identified for ingestion or dermal contact with soil or inhalation of particulates and VOCs. Excess lifetime cancer risks potentially associated with exposure to on base receptors are within the current EPA guidance range of 10^{-6} to 10^{-4}. The cumulative excess risk also does not exceed Texas requirements presented in the Texas Administrative Code (TAC), Title 30, Section 335.563(b), which states “the cumulative excess risk to exposed populations (including sensitive subgroups) shall not be greater than one in ten thousand.” However, the TAC goes on to say that media clean-up levels that

represent an upperbound lifetime risk of one in a million shall be used as a goal in setting the clean-up levels.

For future on base residents, potential domestic use of shallow groundwater would result in unacceptably high carcinogenic and systemic risks from direct ingestion as well as from inhalation of volatile constituents while showering. Primary risk drivers or COCs (i.e., contaminants posing significant risks to human health or the environment) for carcinogenic effects included PCE, TCE, arsenic, benzene, and 1,1-DCE. For systemic effects, COCs were arsenic, PCE, TCE, and total xylenes for ingestion and benzene and CB for inhalation while showering (CH2M HILL, 1999).

For future off base residents, potential domestic use of shallow groundwater would result in unacceptably high carcinogenic and systemic risks from direct ingestion as well as from inhalation of volatile constituents while showering. Primary risk drivers or COCs for carcinogenic effects and systemic effects were PCE and TCE (CH2M HILL, 1999**).** However, off base PCE contamination in Plume B is not further addressed by this CMS report (see Section 3.2.2.2).

3.3.1.3 Ecological Risk Characterization

In the western area of Zone 5, a risk to birds was identified from concentrations of DDT in surface soils. This is not a widespread risk because only one surface soil sample in the west area contained DDT at an elevated concentration. Besides this one exception, the contaminants in Zone 5 do not pose a risk to ecological receptors.

3.3.2 Impacts to Risk Characterization from Zone 5 CMS Groundwater Data Evaluation

In Section 3.3.1, COPCs were identified for this CMS from a comprehensive groundwater data set. Two potential impacts (i.e., increases or decreases in the risk estimates) to the Zone 5 risk characterizations summarized above are the addition and/or deletion of COPCs and a substantial increase and/or decrease in the concentration of the COPCs. These potential impacts are discussed below.

3.3.2.1 Comparison of COPCs

Thirty-five groundwater COPCs were identified in the evaluation of Zone 5 CMS groundwater data (Section 3.2.1; Table 3.4). Thirty two COPCs were identified in the risk assessments reported in the Zone 5 RI report (CH2M HILL, 1999). These sets of COPCs were compared to identify COPC additions/deletions that might impact the risk characterizations summarized above. DDT was identified as an RI COPC but was eliminated in this CMS (Section 3.2.1). Four additional COPCs, not previously identified in the RI, were identified during the CMS data evaluation: bromacil, cis-1,2-dichlorethene, iron, and zinc.

3.3.2.2 Comparison of COPC Concentrations

Concentrations of RI COPCs were compared to CMS COPCs. Except for isopropylbenzene and toluene, concentrations of CMS COPCs were higher than RI COPCs. However, the increase in concentrations was only substantial (i.e., greater than one order of magnitude)

for six COPCs – 1,2-DCB, 1,3-dichlorobenzene (1,3-DCB), 1,4-DCB, 2-methylnaphthalene, CB, and sec-butylbenzene.

3.3.3 Impacts to Previous Risk Characterizations

The concentrations of bromacil, cis-1,2-dichloroethene, iron, and zinc were compared to the Texas Risk Reduction Standards No. 2 Media-Specific Concentrations (MSCs) for nonresidential (i.e., worker) use of potable groundwater. These are described under 30 TAC 335.559(d)(1). The maximum verifiable concentration of bromacil (153 µg/L) is less than the MSC (13,300 µg/L); the maximum verifiable concentration of cis-1,2-dichloroethene (220 µg/L) is greater than the MSC (70 µg/L); and the maximum verifiable concentrations of iron (9,370 µg/L) and zinc (370 µg/L) are less than the MSC (30,700 µg/L). Thus, cis-1,2-dichloroethene is a COC for groundwater.

The increased concentrations of 1,2-DCB, 1,3-DCB, 1,4-DCB, 2-methylnaphthalene, CB, and sec-butylbenzene may increase the risk from exposure to groundwater. This is particularly true for CB, which was considered a COC at its lesser concentration in the risk assessments conducted as part of the Zone 5 RI (CH2M HILL, 1999).

In summary, the evaluation of the Zone 5 CMS groundwater data added one COC, cis 1,2-DCE, to the seven groundwater COCs identified in the Zone 5 RI risk assessments (CH2M HILL, 1999) and referenced above in the human risk characterization discussion.

Quantitative (risk assessments in the Zone 5 RI) and qualitative (as discussed above) evaluations of risk indicate that the most significant risks are associated with potential potable use (particularly residential use) of contaminated water from the shallow aquifer. Because these risks are unacceptable (i.e., $>10^{-4}$ to 10^{-6}) remedial action may be warranted at Zone 5 to reduce potential human health risks from exposure to groundwater. Risks from exposure to soils were within acceptable levels as specified by the EPA.

FIGURE 3.1
Typical Lithologic Units of the Quaternary Alluvial Deposits
Kelly Air Force Base

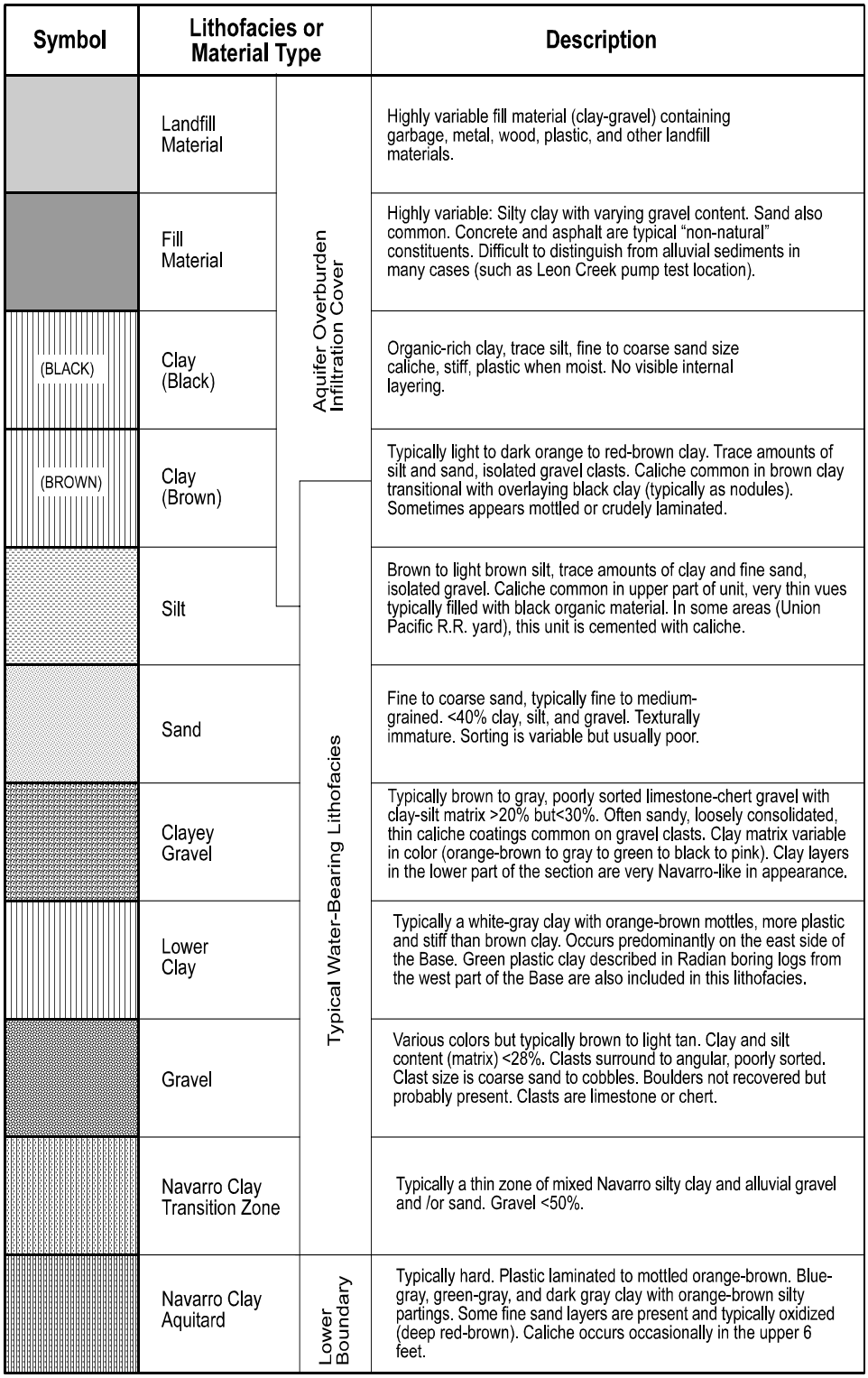

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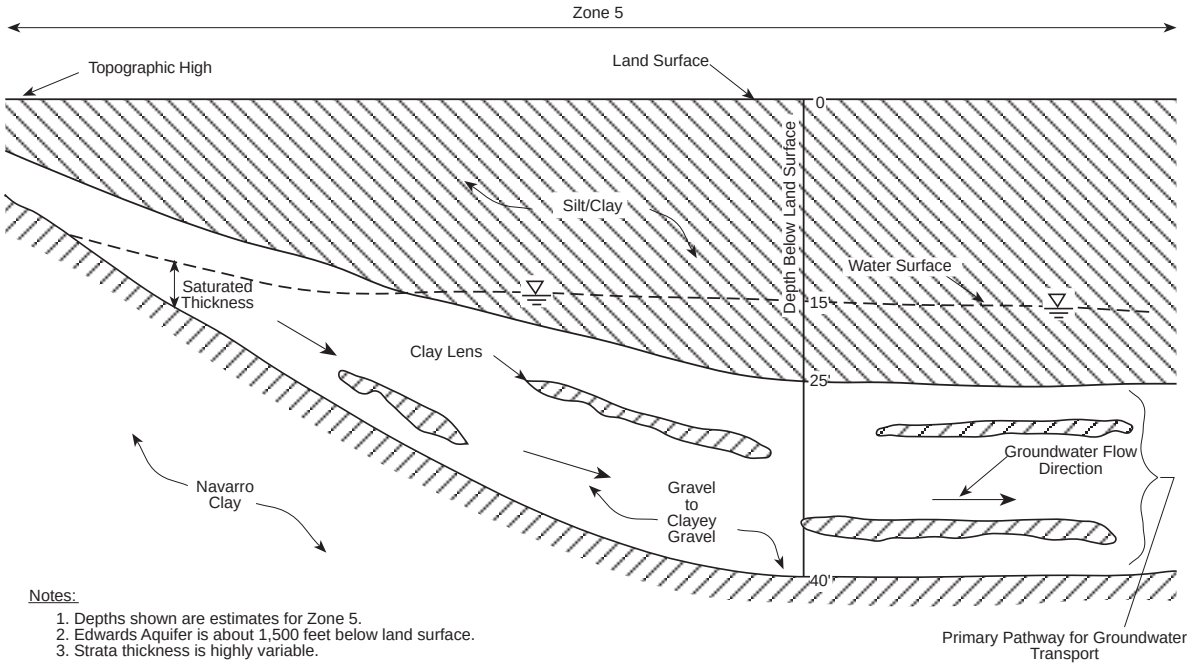
FIGURE 3-2
Potentiometric Surface Map of the Surficial Aquifer, March 2000
Kelly AFB, San Antonio, Texas

CH2MHILL

FIGURE 3.3
Conceptual Hydrogeologic Model
Kelly AFB, San Antonio, Texas



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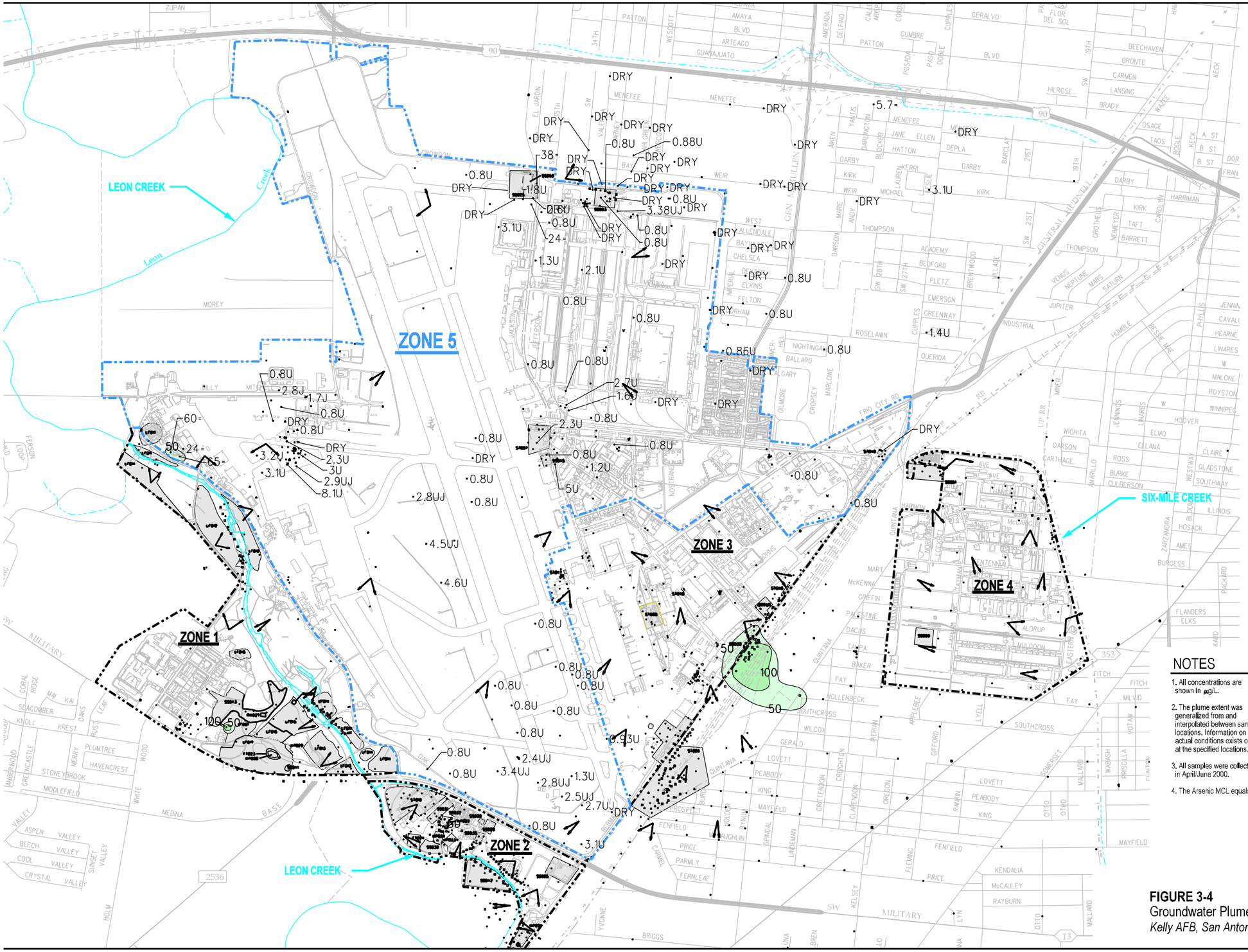


LEGEND

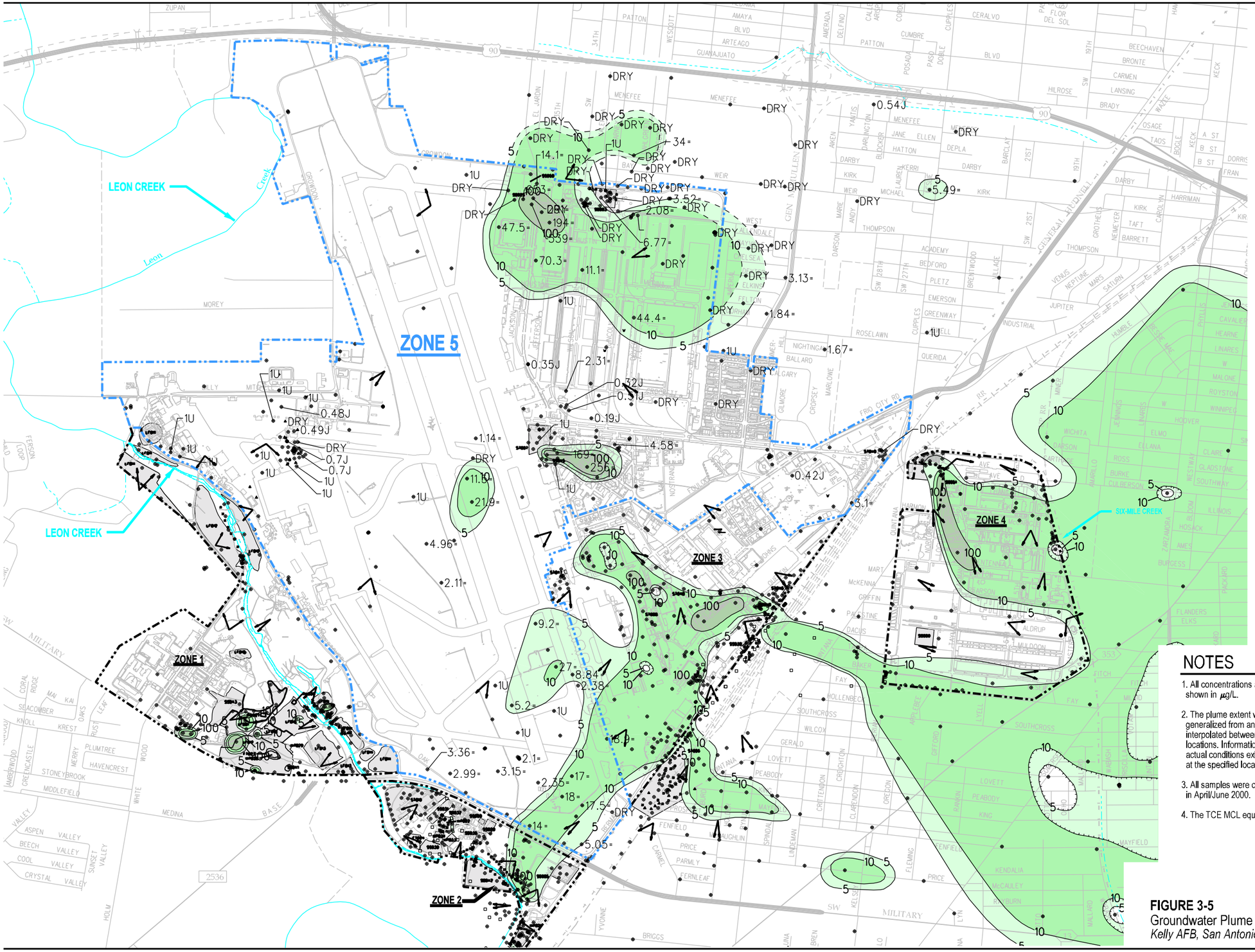
- Recovery Well
- Monitoring Well
- RCRA Monitoring Well
- Abandoned Well
- Operation & Maintenance Monitoring Well
- Edwards Water Supply Well
- Isoconcentration Contour — 10 —
- Inferred Isoconcentration Contour
- Measured Value
- Estimated Value — J
- Undetected — U
- Closed Reduction in Concentration
- Industrial Wastewater System
- Range in Groundwater Flow Direction from March 1994 through September 2000
- Zone 5 Boundary
- Areas of suspected or potential areas for surface and shallow subsurface soil contamination. (0-6' BLS) — WMS 10

NOTES

1. All concentrations are shown in µg/L.
2. The plume extent was generalized from and interpolated between sample locations. Information on actual conditions exists only at the specified locations.
3. All samples were collected in April/June 2000.
4. The Arsenic MCL equals 50 µg/L.

FIGURE 3-4
Groundwater Plume Map of Arsenic
Kelly AFB, San Antonio, Texas

CH2MHILL



LEGEND

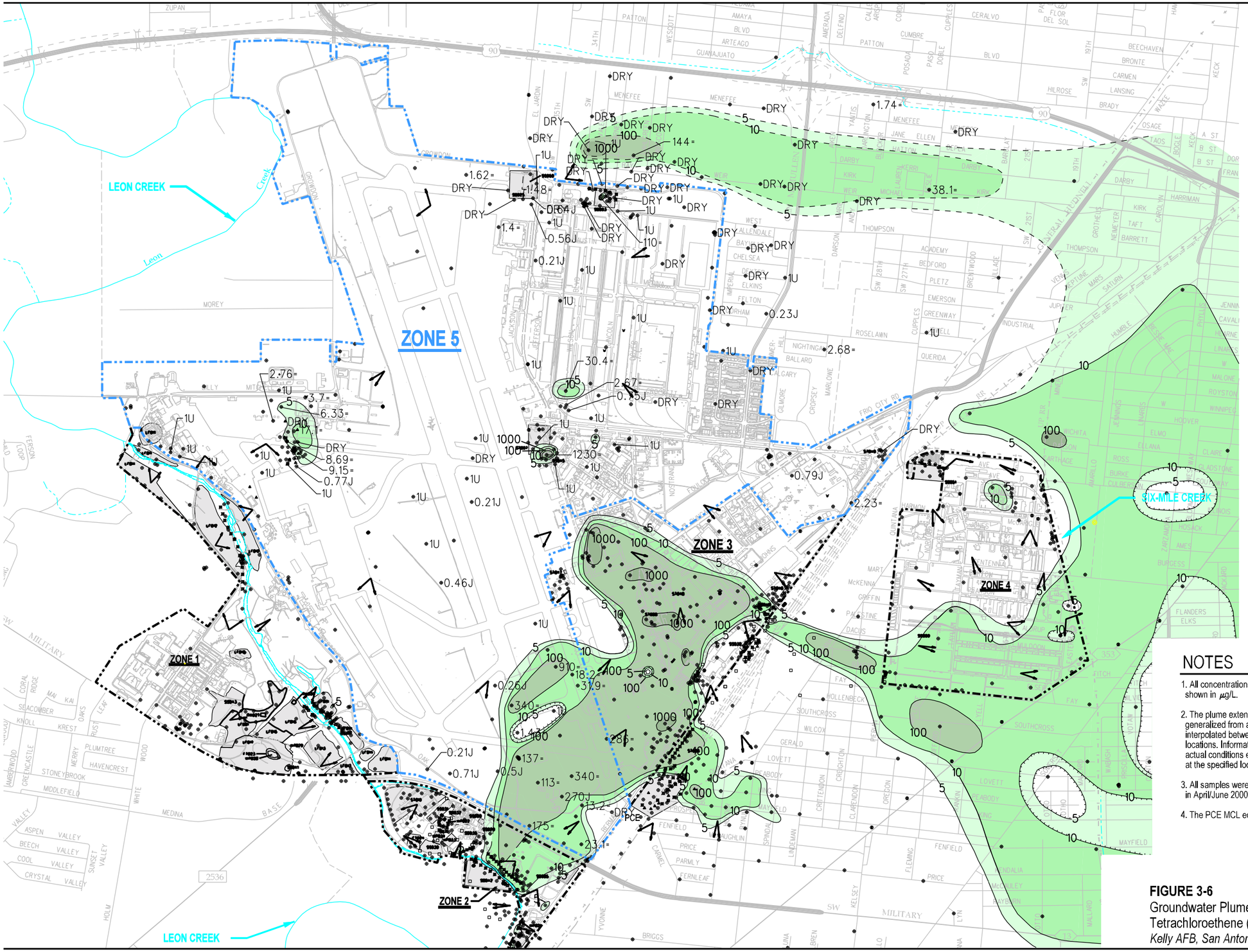
- Recovery Well
- Monitoring Well
- RCRA Monitoring Well
- Abandoned Well
- Operation & Maintenance Monitoring Well
- Edwards Water Supply Well
- Isoconcentration Contour — 10 —
- Inferred Isoconcentration Contour
- Measured Value
- Estimated Value J
- Undetected U
- Closed Reduction in Concentration
- Industrial Wastewater System
- Range in Groundwater Flow Direction from March 1994 through September 2000
- Zone 5 Boundary
- Areas of suspected or potential areas for surface and shallow subsurface soil contamination. (0-6' BLS) WMS 10

NOTES

1. All concentrations are shown in µg/L.
2. The plume extent was generalized from and interpolated between sample locations. Information on actual conditions exists only at the specified locations.
3. All samples were collected in April/June 2000.
4. The TCE MCL equals 5 µg/L.

FIGURE 3-5
Groundwater Plume Map of Trichloroethene (TCE)
Kelly AFB, San Antonio, Texas

CH2MHILL



LEGEND

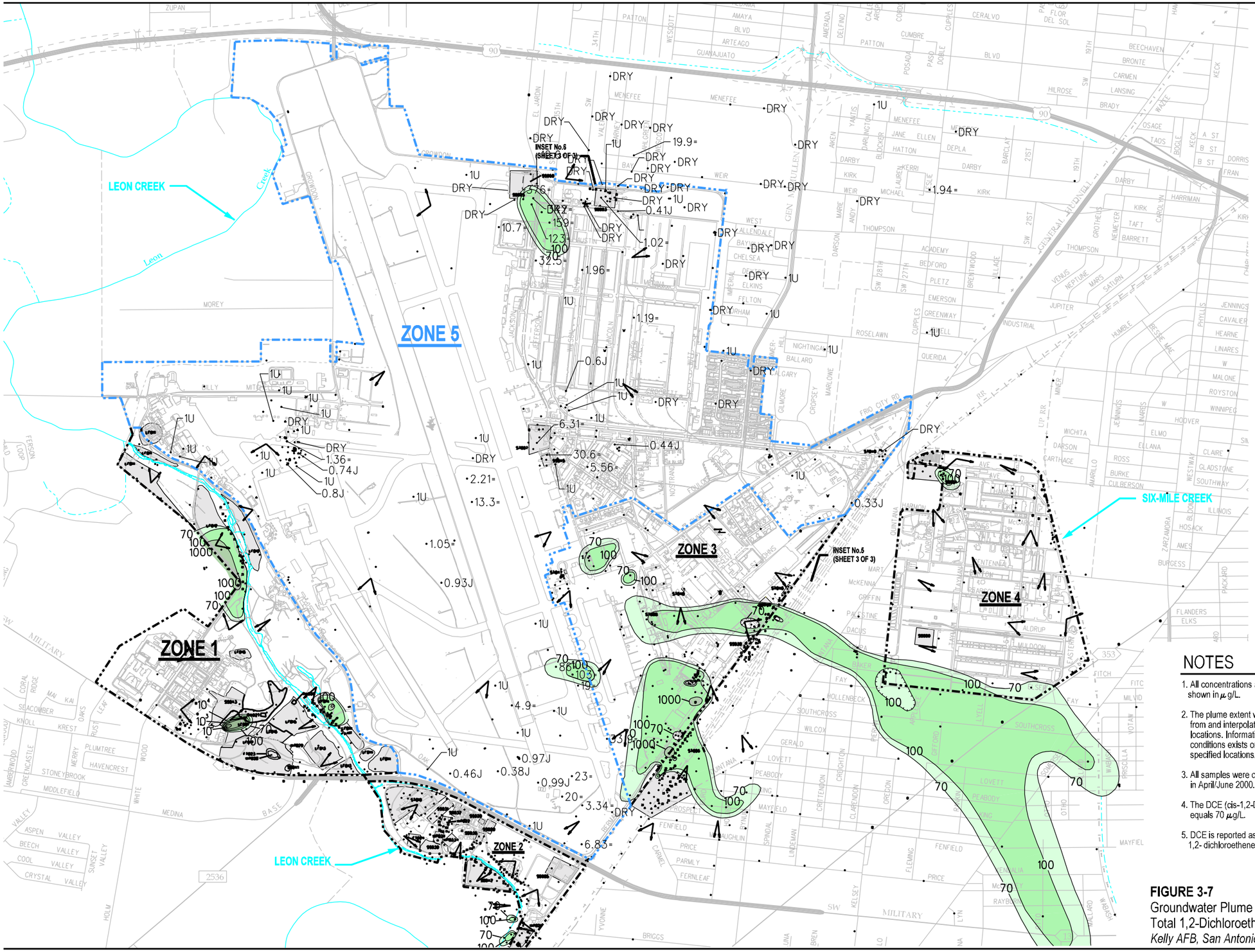
- Recovery Well
- Monitoring Well
- RCRA Monitoring Well
- Abandoned Well
- Operation & Maintenance Monitoring Well
- Edwards Water Supply Well
- Isoconcentration Contour — 10 —
- Inferred Isoconcentration Contour
- Measured Value
- Estimated Value — J
- Undetected — U
- Closed Reduction in Concentration
- Industrial Wastewater System
- Range in Groundwater Flow Direction from March 1994 through September 2000
- Zone 5 Boundary
- Areas of suspected or potential areas for surface and shallow subsurface soil contamination. (0-6' BLS) — WMS 10

NOTES

1. All concentrations are shown in µg/L.
2. The plume extent was generalized from and interpolated between sample locations. Information on actual conditions exists only at the specified locations.
3. All samples were collected in April/June 2000.
4. The PCE MCL equals 5 µg/L.

FIGURE 3-6
Groundwater Plume Map of Tetrachloroethene (PCE)
Kelly AFB, San Antonio, Texas

CH2MHILL



LEGEND

- Recovery Well
- Monitoring Well
- RCRA Monitoring Well
- Abandoned Well
- Operation & Maintenance Monitoring Well
- Edwards Water Supply Well
- Isoconcentration Contour — 10 —
- Inferred Isoconcentration Contour
- Measured Value
- Estimated Value — J
- Undetected — U
- Closed Reduction in Concentration
- Industrial Wastewater System
- Range in Groundwater Flow Direction from March 1994 through September 2000
- Zone 5 Boundary
- Areas of suspected or potential areas for surface and shallow subsurface soil contamination. (0-6' BLS) — WMS 10

N

0 1000' 2000' 3000'

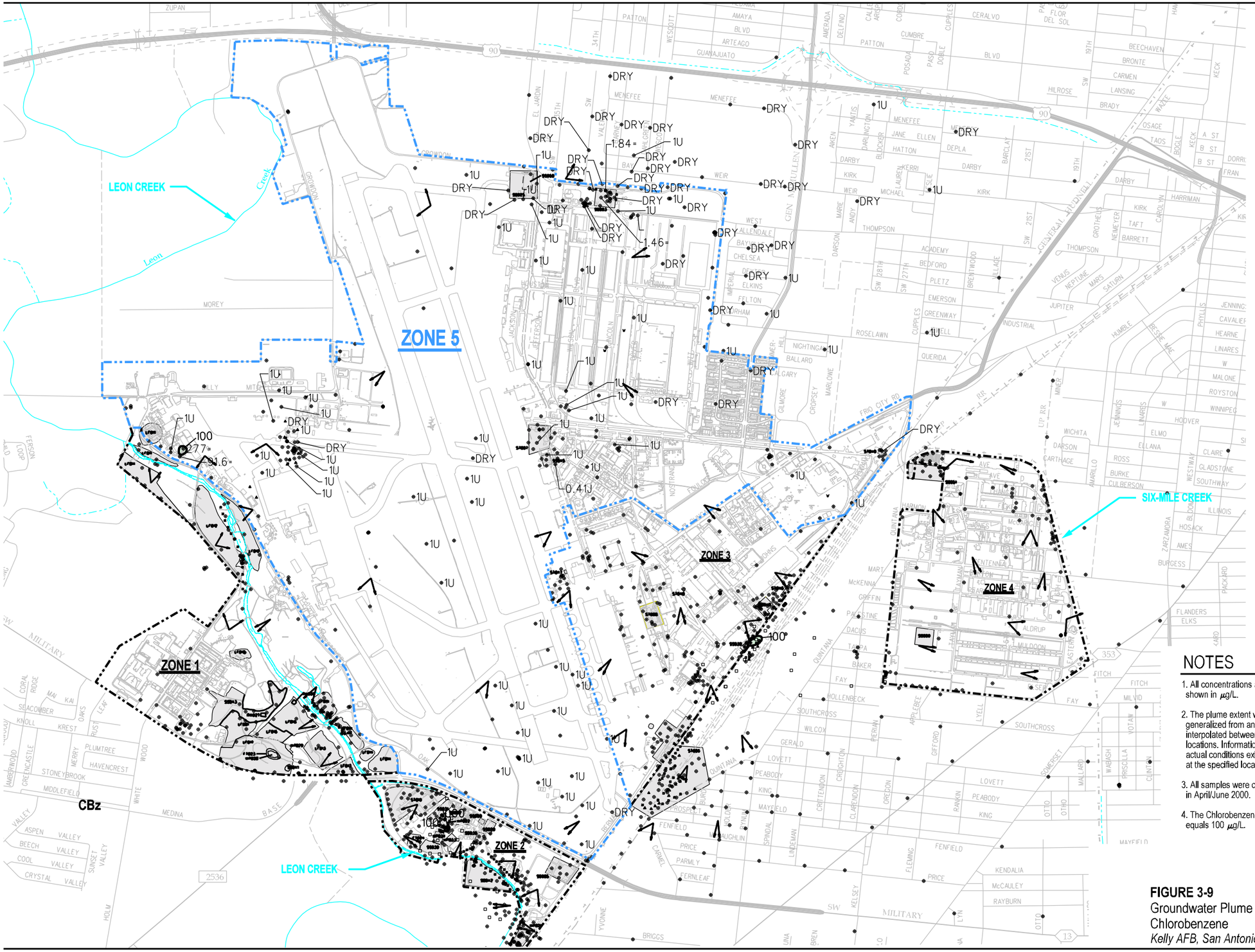
NOTES

1. All concentrations are shown in μg/L.
2. The plume extent was generalized from and interpolated between sample locations. Information on actual conditions exists only at the specified locations.
3. All samples were collected in April/June 2000.
4. The DCE (cis-1,2-DCE) MCL equals 70 μg/L.
5. DCE is reported as total 1,2- dichloroethene.

AIR FORCE BASE CONVERSION AGENCY

FIGURE 3-7
Groundwater Plume Map of
Total 1,2-Dichloroethene (DCE)
Kelly AFB, San Antonio, Texas

CH2MHILL



N

0 1000' 2000' 3000'

LEGEND

- Recovery Well
- Monitoring Well
- RCRA Monitoring Well
- Abandoned Well
- Operation & Maintenance Monitoring Well
- Edwards Water Supply Well
- Isoconcentration Contour — 10 —
- Inferred Isoconcentration Contour
- Measured Value
- Estimated Value — J
- Undetected — U
- Closed Reduction in Concentration
- Industrial Wastewater System
- Range in Groundwater Flow Direction from March 1994 through September 2000
- Zone 5 Boundary
- Areas of suspected or potential areas for surface and shallow subsurface soil contamination. (0-6' BLS) — WMS 10

NOTES

1. All concentrations are shown in µg/L.
2. The plume extent was generalized from and interpolated between sample locations. Information on actual conditions exists only at the specified locations.
3. All samples were collected in April/June 2000.
4. The Chlorobenzene MCL equals 100 µg/L.

FIGURE 3-9
Groundwater Plume Map of Chlorobenzene
Kelly AFB, San Antonio, Texas

AIR FORCE BASE CONVERSION AGENCY

CH2MHILL

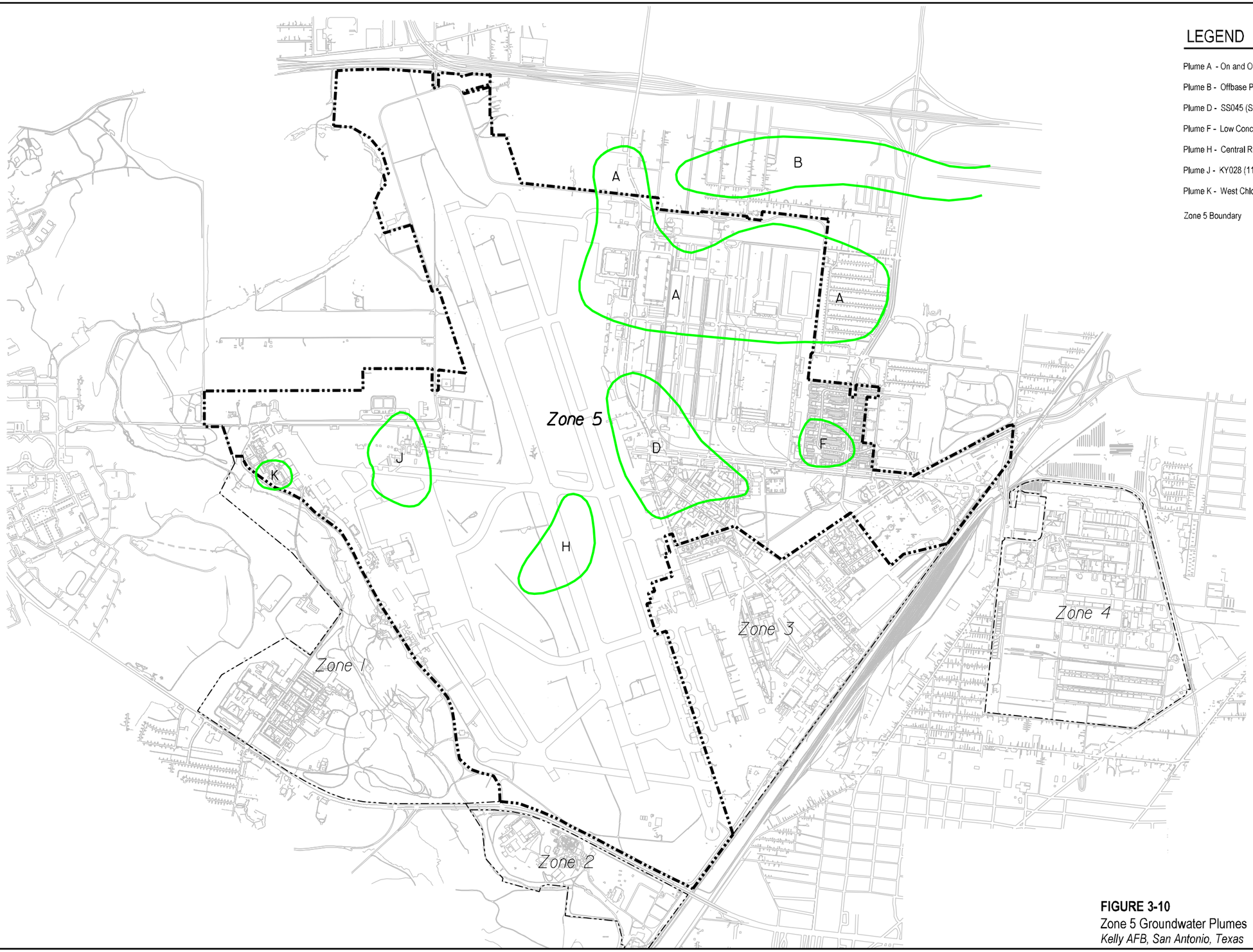


FIGURE 3-10
Zone 5 Groundwater Plumes
Kelly AFB, San Antonio, Texas

CH2MHILL

SAN//CAD/KELLY/159329-Z5CMS/BWC/ 59329-GWPLUME.DLV
26-DEC-01

TABLE 3.1
Thickness of Basal Alluvium and Alluvial Aquifer by Study Area
Kelly AFB, San Antonio, Texas

Study Area	Range of Navarro Group Elevations (NGVD)	Thickness of Basal Alluvium (ft)	Depth to Water Table (ft bls) (avg)	Range in Saturated Thickness of Alluvial Aquifer (ft) (avg)
North	675-640	9-28	14.1-33.3 (27.5)	0-12 (5)
South	665-615	3-26	12-26 (21)	0-16 (6)
West	660-630	6-24	8-34 (26)	2-10 (3-5)
East	660-635	7-32	18-26 (24)	4-17 (10)

NGVD = National Geodetic Vertical Datum
bls = below land surface

TABLE 3.2
Aquifer Properties by Study Area
Kelly AFB, San Antonio, Texas

Study Area	Gradient (ft/ft)	Conductivity (ft/day)	Porosity (%)	Velocity (ft/day)
North Study Area				
S-1 Area	0.005	200	20	5.0
NE Area	0.0029	400	20	5.8
South Study Area				
Mid-Flight Line Area	0.026	50	20	6.5
South Flight Line Area	0.0085	80	20	3.4
West Study Area				
1100 Area	0.0042	77	20	1.6
149th TANG	0.026	4	20	0.52
East Study Area				
IRP sites S-5/S-10	0.002	21	20	0.21
Intersection of Duncan Drive and Tinker Drive	0.003	50	20	0.75
Base Service Station	0.008	80	20	3.2
CE Motor Pool (B38)	0.01	38	20	1.9

TABLE 3.3
Summary of COPC Determination Steps 1 through 3
Kelly AFB, San Antonio, Texas

Constituent Name	Chemical Group	Number of Wells Sampled	Number of Wells Detected	Number of Samples	Number of Detects	Units	Min	Max	Avg	Percent of Samples with Detects	RI COPC?	Crit	Basis	Excd?	> or = 5% of Samples with Detects	Crit*10	if <5%, Excd Crit*10?	CMS COPC?	Final COPC?	Reason for COPC decisions
ANTIMONY	MET	73	4	73	4	mg/L	1.32E-03	5.85E-03	2.60E-03	5.5%	No	6.00E-03	MCL	No	Yes	N/A	N/A	No	No	No exceedances
ARSENIC	MET	73	8	73	8	mg/L	1.70E-03	6.50E-02	2.77E-02	11.0%	Yes	5.00E-02	MCL	Yes	Yes	N/A	N/A	Yes	Yes	RI & CMS COPC
BARIUM	MET	73	73	73	73	mg/L	3.70E-02	8.10E-01	1.13E-01	100.0%	No	2.00E+00	MCL	No	Yes	N/A	N/A	No	No	No exceedances
BERYLLIUM	MET	73	20	73	20	mg/L	7.00E-05	5.50E-02	3.67E-03	27.4%	No	4.00E-03	MCL	Yes	Yes	N/A	N/A	Yes	Yes	CMS COPC
CADMIUM	MET	73	1	73	1	mg/L	2.00E-03	2.00E-03	2.00E-03	1.4%	No	5.00E-03	MCL	No	No	5.00E-02	No	No	No	< 5%
CHROMIUM, TOTAL	MET	73	35	73	35	mg/L	4.98E-03	3.10E+00	1.59E-01	47.9%	Yes	1.00E-01	MCL	Yes	Yes	N/A	N/A	Yes	Yes	RI & CMS COPC
COBALT	MET	73	23	73	23	mg/L	3.00E-04	4.60E-02	6.65E-03	31.5%	Yes	9.40E-01	PRG	No	Yes	N/A	N/A	No	Yes	RI COPC
COPPER	MET	73	10	73	10	mg/L	9.70E-03	7.60E-02	2.99E-02	13.7%	No	1.00E+00	SMCL	No	Yes	N/A	N/A	No	No	No exceedances
CYANIDE	MET	73	1	73	1	mg/L	3.00E-03	3.00E-03	3.00E-03	1.4%	No	2.00E-01	MCL	No	No	2.00E+00	No	No	No	< 5%
LEAD	MET	73	41	73	41	mg/L	1.20E-03	9.90E-02	7.32E-03	56.2%	Yes	1.50E-02	MSC	Yes	Yes	N/A	N/A	Yes	Yes	RI & CMS COPC
MANGANESE	MET	73	49	73	49	mg/L	4.90E-03	3.00E+00	3.01E-01	67.1%	Yes	N/A	N/A	N/A	Yes	N/A	N/A	Yes	Yes	RI & CMS COPC
MERCURY	MET	73	3	73	3	mg/L	3.00E-05	9.70E-05	5.97E-05	4.1%	No	2.00E-03	MCL	No	No	2.00E-02	No	No	No	< 5%
NICKEL	MET	73	48	73	48	mg/L	1.30E-03	4.40E+00	2.13E-01	65.8%	Yes	1.00E-01	MCL	Yes	Yes	N/A	N/A	Yes	Yes	RI & CMS COPC
SELENIUM	MET	73	49	73	49	mg/L	1.00E-03	1.32E-02	2.51E-03	67.1%	No	5.00E-02	MCL	No	Yes	N/A	N/A	No	No	No exceedances
SILVER	MET	73	17	73	17	mg/L	8.50E-04	5.60E-03	1.67E-03	23.3%	No	1.83E-01	MSC	No	Yes	N/A	N/A	No	No	No exceedances
THALLIUM	MET	73	2	73	2	mg/L	2.65E-03	3.21E-03	2.93E-03	2.7%	No	2.00E-03	MCL	Yes	No	2.00E-02	No	No	No	< 5%
VANADIUM	MET	73	22	73	22	mg/L	4.10E-03	6.40E-01	5.75E-02	30.1%	Yes	1.10E-01	PRG	Yes	Yes	N/A	N/A	Yes	Yes	RI & CMS COPC
ZINC	MET	73	6	73	6	mg/L	6.10E-03	5.70E-01	1.80E-01	8.2%	No	5.00E+00	SMCL	No	Yes	N/A	N/A	No	No	No exceedances
1,2-DICHLOROBENZENE	SVOC	72	1	72	1	mg/L	5.03E-03	5.03E-03	5.03E-03	1.4%	Yes	6.00E-01	MCL	No	No	6.00E+00	No	No	No	RI COPC but < 5%
1,3-DICHLOROBENZENE	SVOC	72	1	72	1	mg/L	6.72E-03	6.72E-03	6.72E-03	1.4%	Yes	6.00E-01	MCL	No	No	6.00E+00	No	No	No	RI COPC but < 5%
1,4-DICHLOROBENZENE	SVOC	72	2	72	2	mg/L	4.62E-03	3.35E-02	1.91E-02	2.8%	Yes	7.50E-02	MCL	No	No	7.50E-01	No	No	No	RI COPC but < 5%
bis(2-ETHYLHEXYL) PHTHALATE	SVOC	72	3	72	3	mg/L	2.60E-03	8.02E-03	5.14E-03	4.2%	No	6.00E-03	MSC	Yes	No	6.00E-02	No	No	No	< 5%
DIMETHYL PHTHALATE	SVOC	72	3	72	3	mg/L	2.60E-03	3.10E-03	2.93E-03	4.2%	No	N/A	N/A	N/A	No	N/A	N/A	No	No	< 5%
DI-n-BUTYL PHTHALATE	SVOC	72	3	72	3	mg/L	2.41E-03	3.54E-03	2.98E-03	4.2%	No	N/A	N/A	N/A	No	N/A	N/A	No	No	< 5%
DI-n-OCTYLPHTHALATE	SVOC	72	2	72	2	mg/L	5.41E-03	5.45E-03	5.43E-03	2.8%	No	7.30E-01	MSC	No	No	7.30E+00	No	No	No	< 5%
PHENOL	SVOC	67	2	67	2	mg/L	4.70E-03	5.20E-03	4.95E-03	3.0%	No	2.19E+01	MSC	No	No	2.19E+02	No	No	No	< 5%
1,1,1-TRICHLOROETHANE	VOC	73	3	73	3	mg/L	7.20E-04	2.82E-02	9.90E-03	4.1%	Yes	2.00E-01	MCL	No	No	2.00E+00	No	No	No	RI COPC but < 5%
1,1,2-TRICHLOROETHANE	VOC	73	5	73	5	mg/L	3.10E-04	5.00E-03	1.45E-03	6.8%	No	5.00E-03	MCL	No	Yes	N/A	N/A	No	No	No exceedances
1,1-DICHLOROETHANE	VOC	73	12	73	12	mg/L	2.50E-04	6.35E-03	1.76E-03	16.4%	Yes	3.65E+00	MSC	No	Yes	N/A	N/A	No	Yes	RI COPC
1,1-DICHLOROETHENE	VOC	73	10	73	10	mg/L	3.00E-04	6.81E-03	2.32E-03	13.7%	Yes	7.00E-03	MCL	No	Yes	N/A	N/A	No	Yes	RI COPC
1,2-DICHLOROPROPANE	VOC	73	1	73	1	mg/L	3.10E-04	3.10E-04	3.10E-04	1.4%	No	5.00E-03	MCL	No	No	5.00E-02	No	No	No	< 5%
ACETONE	VOC	69	2	69	2	mg/L	3.47E-03	9.37E-02	4.86E-02	2.9%	No	3.65E+00	MSC	No	No	3.65E+01	No	No	No	< 5%
BENZENE	VOC	73	4	73	4	mg/L	4.80E-04	1.23E-02	4.54E-03	5.5%	No	5.00E-03	MCL	Yes	Yes	N/A	N/A	Yes	Yes	CMS COPC
CARBON TETRACHLORIDE	VOC	73	1	73	1	mg/L	4.70E-04	4.70E-04	4.70E-04	1.4%	No	5.00E-03	MCL	No	No	5.00E-02	No	No	No	< 5%
CHLOROBENZENE	VOC	73	6	73	6	mg/L	4.10E-04	2.77E-01	6.22E-02	8.2%	Yes	1.00E-01	MSC	Yes	Yes	N/A	N/A	Yes	Yes	RI & CMS COPC
CHLOROETHANE	VOC	73	1	73	1	mg/L	2.40E-04	2.40E-04	2.40E-04	1.4%	Yes	7.30E-01	MSC	No	No	7.30E+00	No	No	No	RI COPC but < 5%
CHLOROFORM	VOC	73	22	73	22	mg/L	1.90E-04	1.41E-03	5.75E-04	30.1%	No	1.00E-01	MCL	No	Yes	N/A	N/A	No	No	No exceedances
cis-1,2-DICHLOROETHYLENE	VOC	73	43	73	43	mg/L	1.70E-04	3.73E-01	3.17E-02	58.9%	No	7.00E-02	MCL	Yes	Yes	N/A	N/A	Yes	Yes	CMS COPC
METHYL ETHYL KETONE (2-BUTANONE)	VOC	73	3	73	3	mg/L	2.43E-03	4.63E-03	3.56E-03	4.1%	No	1.83E+00	MSC	No	No	1.83E+01	No	No	No	< 5%
METHYL ISOBUTYL KETONE (4-METHYL-2-PENTANONE)	VOC	73	1	73	1	mg/L	1.49E-03	1.49E-03	1.49E-03	1.4%	No	1.83E+00	MSC	No	No	1.83E+01	No	No	No	< 5%
METHYLENE CHLORIDE	VOC	73	1	73	1	mg/L	1.49E-03	1.49E-03	1.49E-03	1.4%	No	5.00E-03	MCL	No	No	5.00E-02	No	No	No	< 5%
TETRACHLOROETHYLENE(PCE)	VOC	73	40	73	40	mg/L	2.10E-04	1.23E+00	9.45E-02	54.8%	Yes	5.00E-03	MCL	Yes	Yes	N/A	N/A	Yes	Yes	RI & CMS COPC
TOLUENE	VOC	73	9	73	9	mg/L	1.80E-04	9.80E-04	4.09E-04	12.3%	Yes	1.00E+00	MCL	No	Yes	N/A	N/A	No	Yes	RI COPC
TOTAL 1,2-DICHLOROETHENE	VOC	73	38	73	38	mg/L	3.30E-04	3.76E-01	3.67E-02	52.1%	Yes	7.00E-02	MCL	Yes	Yes	N/A	N/A	Yes	Yes	RI & CMS COPC
trans-1,2-DICHLOROETHENE	VOC	73	14	73	14	mg/L	2.70E-04	1.84E-02	2.87E-03	19.2%	No	1.00E-01	MCL	No	Yes	N/A	N/A	No	No	No exceedances
TRICHLOROETHYLENE (TCE)	VOC	73	51	73	51	mg/L	1.90E-04	6.53E-01	4.94E-02	69.9%	Yes	5.00E-03	MCL	Yes	Yes	N/A	N/A	Yes	Yes	RI & CMS COPC
VINYL CHLORIDE	VOC	73	5	73	5	mg/L	6.60E-04	1.76E-03	1.01E-03	6.8%	Yes	2.00E-03	MCL	No	Yes	N/A	N/A	No	Yes	RI COPC
XYLENES, TOTAL	VOC	73	1	73	1	mg/L	9.60E-04	9.60E-04	9.60E-04	1.4%	Yes	1.00E+01	MCL	No	No	1.00E+02	No	No	No	RI COPC but < 5%

Table 3.4

Summary of Constituents of Potential Concern (COPCs) In Groundwater and Their Maximum Verifiable Concentration
Kelly AFB, Texas

Constituent Name	Chemical Group	Units	Max
ARSENIC	MET	mg/L	6.50E-02
BERYLLIUM	MET	mg/L	5.50E-02
CHROMIUM, TOTAL	MET	mg/L	3.10E+00
COBALT	MET	mg/L	4.60E-02
LEAD	MET	mg/L	9.90E-02
MANGANESE	MET	mg/L	3.00E+00
NICKEL	MET	mg/L	4.40E+00
VANADIUM	MET	mg/L	6.40E-01
1,1-DICHLOROETHANE	VOC	mg/L	6.35E-03
1,1-DICHLOROETHENE	VOC	mg/L	6.81E-03
BENZENE	VOC	mg/L	1.23E-02
CHLOROBENZENE	VOC	mg/L	2.77E-01
cis-1,2-DICHLOROETHYLENE	VOC	mg/L	3.73E-01
TETRACHLOROETHYLENE(PCE)	VOC	mg/L	1.23E+00
TOLUENE	VOC	mg/L	9.80E-04
TOTAL 1,2-DICHLOROETHENE	VOC	mg/L	3.76E-01
TRICHLOROETHYLENE (TCE)	VOC	mg/L	6.53E-01
VINYL CHLORIDE	VOC	mg/L	1.76E-03

TABLE 3.5

Results of Constituents of Potential Concern (COPC) Identification for Metals in Groundwater
Kelly AFB, Texas

Constituent Name	Chemical Group	Units	Maximum Verifiable Concentration	TNRCC Standard
ARSENIC	MET	mg/L	6.50E-02	5.00E-02
BERYLLIUM	MET	mg/L	5.50E-02	4.00E-03
CHROMIUM, TOTAL	MET	mg/L	3.10E+00	1.00E-01
COBALT	MET	mg/L	4.60E-02	9.40E-01
LEAD	MET	mg/L	9.90E-02	1.50E-02
MANGANESE	MET	mg/L	3.00E+00	N/A
NICKEL	MET	mg/L	4.40E+00	1.00E-01
VANADIUM	MET	mg/L	6.40E-01	1.10E-01

TABLE 3.6

Summary of Metals Evaluation at Individual Monitoring Wells

Kelly AFB, San Antonio, Texas

Well Location	Standard Exceeded	Description of Detected Chemicals per Well
KY019MW001	None	Barium, Beryllium, 1,1,1-TCA, Chloroform, PCE and TCE were detected at this well. There were no exceedances to criteria.
KY028MW019	None	Barium, Manganese, Di-n-Butylphthalate, Benzene and PCE were detected at this well. There were no exceedances to criteria.
KY028MW024	PCE	Barium, Manganese, Selenium, 1,2-DCE (cis and total), PCE, TCE and Vinyl chloride were detected at this well. PCE (8.7 ug/L) was the only exceedance to criteria.
KY028MW027	Beryllium, PCE	The maximum detected value of Beryllium was detected at this well at 55 ug/L. Barium, Manganese, Nickel, 1,2-DCE (cis), PCE and TCE were also detected at this well. Beryllium and PCE (17 ug/L) were the only exceedances to criteria.
KY028MW030	None	The maximum detected value of Vinyl chloride was detected at this well at 1.8 ug/L. Barium, Cobalt, Manganese, and 1,2-DCE (cis and total) were also detected at this well. There were no exceedances to criteria.
KY028MW033	PCE	Barium, Manganese, 1,2-DCE (cis and total), PCE and TCE were detected at this well. PCE (9.2 ug/L) was the only exceedance to criteria.
KY029MW017	Nickel	Barium, Beryllium, Chromium, Cobalt, Manganese, Nickel and Selenium were detected at this well. Nickel (360 ug/L) was the only exceedance to criteria.
SS003MW003	TCE	Barium, Beryllium, Vanadium, Chlorobenzene, 1,2-DCE (cis and total) and TCE were detected at this well. TCE (11 ug/L) was the only exceedance to criteria.
SS003MW008	None	Barium, Chromium, Manganese, Nickel, Vanadium, 1,2-DCE (cis and total) and TCE were detected at this well. There were no exceedances to criteria.
SS003MW013	PCE, TCE	Barium, Chromium, Lead, Nickel, Selenium, Silver, Vanadium, 1,2-DCE (cis and total), PCE and TCE were detected at this well. PCE (144 ug/L) and TCE (34 ug/L) were the only exceedances to criteria.
SS003MW018	Not applicable	No data for this well.
SS003MW019	None	Barium, Beryllium, Manganese and Chlorobenzene were detected at this well. There were no exceedances to criteria.
SS003MW020	PCE, TCE	Barium, Beryllium, Manganese, Selenium, Bis(2-ethylhexyl)phthalate, Chlorobenzene,1,2-DCE (cis and total), PCE and TCE were detected at this well. PCE (110 ug/L) and TCE (6.8 ug/L) were the only exceedances to criteria.
SS025MW006	TCE	Antimony, Arsenic, Barium, Beryllium, Cobalt, Copper, Manganese, Nickel, Vanadium, 1,2-DCE (cis and total) and TCE were detected at this well. TCE (14 ug/L) was the only exceedance to criteria.
SS050MW003	None	The maximum detected values of Phenol and MIBK were detected at this well at 5.2 and 1.5 ug/L, respectively. Barium, Copper, Lead, Manganese, Nickel, Selenium, Dimethylphthalate, MEK and TCE were also detected at this well. There were no exceedances to criteria.
SS050MW008	None	Barium, Beryllium, Chromium, Manganese, Nickel, Selenium, Vanadium and TCE were detected at this well. There were no exceedances to criteria.

TABLE 3.6
Summary of Metals Evaluation at Individual Monitoring Wells
Kelly AFB, San Antonio, Texas

Well Location	Standard Exceeded	Description of Detected Chemicals per Well
SS050MW019	TCE	Barium, Beryllium, Lead, Selenium, 1,2-DCE (cis and trans) and TCE were detected at this well. TCE (9.2 ug/L) was the only exceedance to criteria.
SS050MW022	TCE	Barium, Copper, Selenium, Silver, Vanadium, 1,1-DCE, 1,2-DCE (cis and total) and TCE were detected at this well. TCE (44 ug/L) was the only exceedance to criteria.
SS050MW024	None	Arsenic, Barium, Mercury, Selenium, Dimethylphthalate and PCE were detected at this well. There were no exceedances to criteria.
SS050MW030	Nickel	Barium, Chromium, Lead, Nickel, Selenium, Silver, Di-n-butylphthalate and PCE were detected at this well. Nickel (140 ug/L) was the only exceedance to criteria.
SS050MW042	TCE	The maximum detected value of Cyanide was detected at this well at 3 ug/L. Barium, Cyanide, Lead, Manganese, Nickel, Vanadium, Phenol, 1,2-DCE (cis and total) and TCE were also detected at this well. TCE (11 ug/L) was the only exceedance to criteria.
SS050MW044	Chromium, Nickel, 1,2-DCE (cis and total), TCE	The maximum detected values of Chromium, Cobalt, Nickel and 1,1-DCE were detected at this well at 3100, 46, 4400, and 6.8 ug/L, respectively. Arsenic, Barium, Copper, Lead, Manganese, Selenium, Vanadium, 1,1,2-TCA, 1,1-DCA, Chloroform, 1,2-DCE (cis, trans, and total), PCE and TCE were also detected at this well. Chromium, Nickel, 1,2-DCE (cis) (123 ug/L), 1,2-DCE (total) (123 ug/L), and TCE (539 ug/L) were the only exceedances to criteria.
SS050MW047	TCE	Barium, Chromium, Cobalt, Lead, Manganese, Nickel, Selenium, Vanadium, 1,1-DCA, 1,1-DCE, Chloroform, 1,2-DCE (cis, trans, and total), PCE and TCE were detected at this well. TCE (70 ug/L) was the only exceedance to criteria.
SS050MW048	None	Barium, Nickel, Chloroform, 1,2-DCE (cis and total), PCE and TCE were detected at this well. There were no exceedances to criteria.
SS050MW050	PCE, TCE	Barium, Chromium, Cobalt, Lead, Manganese, Nickel, Selenium, Chloroform, 1,2-DCE (cis, trans, and total), PCE and TCE were detected at this well. PCE (340 ug/L) and TCE (17 ug/L) were the only exceedances to criteria.
SS050MW051	PCE	Barium, Chromium, Cobalt, Manganese, Nickel, Selenium, 1,2-DCE (cis and total), PCE and TCE were detected at this well. PCE (137 ug/L) was the only exceedance to criteria.
SS050MW052	PCE, TCE	Barium, Chromium, Cobalt, Manganese, Nickel, Selenium, 1,1-DCA, Chloroform, 1,2-DCE (cis, trans, and total), PCE and TCE were detected at this well. PCE (270 ug/L) and TCE (18 ug/L) were the only exceedances to criteria.
SS050MW053	PCE	Barium, Cobalt, Manganese, Nickel, 1,2-DCE (cis and total), PCE and TCE were detected at this well. PCE (113 ug/L) was the only exceedance to criteria.

TABLE 3.6
Summary of Metals Evaluation at Individual Monitoring Wells
Kelly AFB, San Antonio, Texas

Well Location	Standard Exceeded	Description of Detected Chemicals per Well
SS050MW056	Nickel, 1,2-DCE (cis and total), PCE, TCE	Barium, Chromium, Lead, Manganese, Nickel, Selenium, 1,1-DCA, Chloroform, 1,2-DCE (cis and total), PCE and TCE were detected at this well. Nickel (120 ug/L), 1,2-DCE (cis) (103 ug/L), 1,2-DCE (total) (103 ug/L), PCE (18 ug/L) and TCE (8.8 ug/L) were the only exceedances to criteria.
SS050MW057	Chromium, Nickel	The maximum detected value of Di-n-Octylphthalate was detected at this well at 5.5 ug/L. Barium, Chromium, Cobalt, Lead, Manganese and Selenium were also detected at this well. Chromium (120 ug/L) and Nickel (2800 ug/L) were the only exceedances to criteria.
SS050MW058	None	Barium, Lead and PCE were detected at this well. There were no exceedances to criteria.
SS050MW059	TCE	Barium, Selenium, Silver, Chloroform, 1,2-DCE (cis and total), PCE and TCE were detected at this well. TCE (48 ug/L) was the only exceedance to criteria.
SS050MW061	None	Barium, Beryllium, Chromium, Cobalt, Lead, Manganese, Nickel, Selenium, Vanadium, Chloroform, 1,2-DCE (cis and total), PCE and TCE were detected at this well. There were no exceedances to criteria.
SS050MW093	None	Arsenic, Barium, Beryllium, Chromium, Cobalt, Manganese, Nickel and Selenium were detected at this well. There were no exceedances to criteria.
SS050MW102	None	The maximum detected value of Acetone was detected at this well at 94 ug/L. Barium, Selenium, Silver and TCE were also detected at this well. There were no exceedances to criteria.
SS050MW105	PCE, TCE	Barium, Beryllium, Chromium, Cobalt, Lead, Manganese, Nickel, 1,2-DCE (cis, trans and total), PCE, Toluene and TCE were detected at this well. PCE (23 ug/L) and TCE (5 ug/L) were the only exceedances to criteria.
SS050MW106	1,2-DCE (cis and total), PCE, TCE	The maximum detected value of 1.2-Dichloropropane was detected at this well at 0.31 ug/L. Barium, Chromium, Lead, Nickel, Selenium, Vanadium, 1,1-DCA, 1,1-DCE, Chloroform, 1,2-DCE (cis, trans and total), PCE and TCE were detected at this well. 1,2-DCE (cis) (85 ug/L), 1,2-DCE (total) (86 ug/L), PCE (910 ug/L), and TCE (27 ug/L) were the only exceedances to criteria.
SS050MW109	Nickel, 1,2-DCE (cis and total), TCE	Barium, Beryllium, Chromium, Cobalt, Manganese, Nickel, Selenium, Vanadium, 1,1,2-TCA, 1,1-DCA, 1,1-DCE, Chloroform, 1,2-DCE (cis, trans and total) and TCE were detected at this well. Nickel (280 ug/L), 1,2-DCE (cis) (156 ug/L), 1,2-DCE (total) (159 ug/L), and TCE (194 ug/L) were the only exceedances to criteria.
SS050MW111	None	Barium, Beryllium, Chromium, Lead, Nickel and PCE were detected at this well. There were no exceedances to criteria.
SS050MW112	PCE, TCE	Barium, Beryllium, Chromium, Cobalt, Lead, Manganese, Nickel, Selenium, 1,1-DCA, Chloroform, 1,2-DCE (cis, trans and total), PCE and TCE were detected at this well. PCE (340 ug/L) and TCE (5 ug/L) were the only exceedances to criteria.
SS050MW113	TCE	Barium, Lead, Nickel, Selenium, Chloroform, 1,2-DCE (cis and total) and TCE were detected at this well. TCE (256 ug/L) was the only exceedance to criteria.

TABLE 3.6
Summary of Metals Evaluation at Individual Monitoring Wells
Kelly AFB, San Antonio, Texas

Well Location	Standard Exceeded	Description of Detected Chemicals per Well
SS050MW115	None	Barium, Manganese, Nickel, Selenium, Bis(2-ethylhexyl)phthalate, Chloroform, 1,2-DCE (cis and total), PCE and TCE were detected at this well. There were no exceedances to criteria.
SS050MW119	None	Barium, Chromium, Manganese, Nickel and Selenium were detected at this well. There were no exceedances to criteria.
SS050MW120	None	Barium, Lead, Selenium, Chloroform, 1,2-DCE (cis and total), Toluene and TCE were detected at this well. There were no exceedances to criteria.
SS050MW122	Chromium, Nickel	The maximum detected value of Carbon tetrachloride was detected at this well at 0.47 ug/L. Barium, Chromium, Cobalt, Copper, Lead, Manganese, Nickel, Selenium, Vanadium, Zinc, Chloroform, 1,2-DCE (cis and total), PCE and TCE were also detected at this well. Chromium (770 ug/L) and Nickel (160 ug/L) were the only exceedances to criteria.
SS050MW123	None	Barium, Manganese, Nickel, Selenium, 1,1-DCA, 1,1-DCE, 1,2-DCE (cis), PCE, Toluene and TCE were detected at this well. There were no exceedances to criteria.
SS050MW124	Not applicable	No data for this well.
SS050MW125	None	Barium, Cobalt, Manganese, Nickel, Selenium, 1,2-DCE (cis and total) and TCE were detected at this well. There were no exceedances to criteria.
SS050MW126	Nickel, PCE	The maximum detected value of 1,1,1-TCA was detected at this well at 28 ug/L. Barium, Chromium, Manganese, Nickel, Silver, 1,1-DCE, 1,2-DCE (cis and total), PCE and TCE were also detected at this well. Nickel (170 ug/L) and PCE (30 ug/L) were the only exceedances to criteria.
SS050MW127	None	Barium, Lead, Selenium, Silver, 1,2-DCE (cis) and TCE were detected at this well. There were no exceedances to criteria.
SS050MW133	None	Barium, Nickel and MEK were detected at this well. There were no exceedances to criteria.
SS050MW135	TCE	Barium, Lead, Zinc, 1,2-DCE (cis and total) and TCE were detected at this well. TCE (12 ug/L) was the only exceedance to criteria.
SS050MW136	None	Barium and Dimethylphthalate were detected at this well. There were no exceedances to criteria.
SS050MW145	PCE	Barium, Chromium, Manganese, Selenium, PCE and TCE were detected at this well. PCE (6.3 ug/L) was the only exceedance to criteria.
SS050MW146	None	Barium, Manganese, Selenium and PCE were detected at this well. There were no exceedances to criteria.
SS050MW149	Bis(2-ethylhexyl) phthalate, Benzene, Chlorobenzene	The maximum detected values of Bis(2-ethylhexyl)phthalate, 1,1-DCA, Benzene and Chlorobenzene were detected at this well at 8, 6.4, 12.3 and 277 ug/L, respectively. Arsenic, Barium, Beryllium, Cobalt, Lead, Manganese, Nickel, Selenium, Silver, 1,2-DCB, Di-n-butylphthalate, 1,1-DCE, Toluene and Vinyl chloride were also detected at this well. Bis(2-ethylhexyl)phthalate, Benzene and Chlorobenzene were the only exceedances to criteria.
SS050MW150	None	Barium, Chromium, Lead, Manganese, Nickel, PCE and TCE were detected at this well. There were no exceedances to criteria.

TABLE 3.6
Summary of Metals Evaluation at Individual Monitoring Wells
Kelly AFB, San Antonio, Texas

Well Location	Standard Exceeded	Description of Detected Chemicals per Well
SS050MW152	TCE	Barium, Chromium, Lead, Nickel, Selenium, 1,2-DCE (cis, trans and total), PCE and TCE were detected at this well. TCE (22 ug/L) was the only exceedance to criteria.
SS050MW153	Nickel	The maximum detected value of Mercury was detected at this well at 0.1 ug/L. Barium, Chromium, Lead, Nickel and Selenium were also detected at this well. Nickel (120 ug/L) was the only exceedance to criteria.
SS050MW157	Not applicable	No data for this well.
SS050MW158	Not applicable	No data for this well.
SS050MW166	Not applicable	No data for this well.
SS050MW173	None	Antimony, Barium, Chromium, Lead, Manganese, Nickel, Selenium, Silver and Chloroform were detected at this well. There were no exceedances to criteria.
SS050MW176	Not applicable	No data for this well.
SS050MW183	Not applicable	No data for this well.
SS050MW185	None	The maximum detected values of MEK, Methylene chloride, and Toluene were detected at this well at 4.6, 1.5 and 10 ug/L, respectively. Barium, Lead, Nickel, Silver, PCE and TCE were also detected at this well. There were no exceedances to criteria.
SS050MW186	None	Barium, Chromium, Lead, Nickel, Selenium, Silver, Vanadium, Chloroform and TCE were detected at this well. There were no exceedances to criteria.
SS050MW334	None	Barium, Lead, Selenium, Silver, Vanadium, PCE and TCE were detected at this well. There were no exceedances to criteria.
SS050MW335	Not applicable	No data for this well.
SS050MW336	None	Arsenic, Barium, Beryllium, Chromium, Cobalt, Lead, Manganese, Nickel, Selenium, Silver, PCE and TCE were detected at this well. There were no exceedances to criteria
SS050MW337	None	The maximum detected value of Antimony was detected at this well at 5.9 ug/L. Barium, Beryllium, Chromium, Copper, Lead, Manganese, Nickel, Vanadium, Zinc and Toluene were also detected at this well. There were no exceedances to criteria.
SS050MW338	PCE, TCE	Barium, Chromium, Cobalt, Lead, Manganese, Nickel, Selenium, Vanadium, Chloroform, 1,2-DCE (cis and total), PCE and TCE were detected at this well. PCE (38 ug/L) and TCE (5.5 ug/L) were the only exceedances to criteria.
SS050MW339	Not applicable	No data for this well.
SS050MW340	None	Barium, Lead, Manganese, Selenium, Vanadium, Toluene and TCE were detected at this well. There were no exceedances to criteria.
SS050MW341	PCE	Barium, Chromium, Cobalt, Copper, Lead, Manganese, Nickel, Selenium, Vanadium, Chloroform, 1,2-DCE (cis and total), PCE, Toluene and TCE were detected at this well. PCE (6.8 ug/L) was the only exceedance to criteria.
SS050MW342	Not applicable	No data for this well.

TABLE 3.6

Summary of Metals Evaluation at Individual Monitoring Wells

Kelly AFB, San Antonio, Texas

Well Location	Standard Exceeded	Description of Detected Chemicals per Well
SS050MW344	Not applicable	No data for this well.
SS050MW356	Arsenic, Beryllium, Chromium, Lead, Nickel, Thallium, Vanadium	The maximum detected values of Cadmium, Copper, Lead, Selenium, Silver, Thallium, Vanadium, and Zinc were detected at this well at 2, 76, 99, 13, 5.6, 3.2, 640 and 570 ug/L, respectively. Barium, Cobalt, Manganese and Mercury were also detected at this well. Arsenic (60 ug/L), Beryllium (10 ug/L), Chromium (400 ug/L), Lead, Nickel (140 ug/L), Thallium and Vanadium were the exceedances to criteria.
SS050MW357	Arsenic, Beryllium, Chromium, Lead, Thallium, Vanadium	The maximum detected values of Arsenic, Barium, 1,2-DCB, 1,3-DCB, 1,4-DCB and Chloroethane were detected at this well at 65, 810, 5, 6.7, 34 and 0.24 ug/L, respectively. Antimony, Beryllium, Chromium, Cobalt, Copper, Lead, Manganese, Nickel, Selenium, Silver, Thallium, Vanadium, Zinc, 1,1-DCA, Chlorobenzene and 1,2-DCE (cis) were also detected at this well. Arsenic, Beryllium (6 ug/L), Chromium (240 ug/L), Lead (81 ug/L), Thallium (2.65 ug/L), and Vanadium (420 ug/L) were the exceedances to criteria.
SS050MW469	Not applicable	No data for this well.
SS050MW470	1,2-DCE (cis and total), TCE	The maximum detected values of Chloroform, 1,2-DCE (total) and TCE were detected at this well at 1.4, 376 and 653 ug/L, respectively. Barium, Lead, Manganese, Selenium, 1,1,2-TCA, 1,1-DCA, 1,1-DCE, 1,2-DCE (cis and trans), and PCE were also detected at this well. 1,2-DCE (cis) (373 ug/L), 1,2-DCE (total) and TCE were the only exceedances to criteria.
SS050MW471	Chromium, Nickel, 1,2-DCE (cis and total), TCE	The maximum detected value of 1,1,2-TCA was detected at this well at 5 ug/L. Barium, Chromium, Copper, Lead, Manganese, Nickel, Selenium, 1,1,1-TCA, 1,1-DCA, 1,1-DCE, Chloroform, 1,2-DCE (cis, trans and total), PCE and TCE were also detected at this well. Chromium (170 ug/L), Nickel (700 ug/L), 1,2-DCE (cis) (324 ug/L), 1,2-DCE (total) (342 ug/L) and TCE (291 ug/L) were the only exceedances to criteria.
SS050MW472	None	The maximum detected value of Total Xylenes was detected at this well at 1 ug/L. Barium, Lead, Manganese, Nickel, Silver, Zinc, Benzene, Chlorobenzene, and Toluene were also detected at this well. There were no exceedances to criteria.
SS050MW473	Not applicable	No data for this well.
ST007MW008	None	Barium, Lead, Manganese, Acetone, Benzene, 1,2-DCE (cis, trans and total), and Vinyl chloride were detected at this well. There were no exceedances to criteria.
ST007MW053	PCE, TCE	The maximum detected value of PCE was detected at this well at 1230 ug/L. Barium, Lead, Manganese, Selenium, Silver, Di-n-octylphthalate, 1,1,2-TCA, 1,2-DCE (cis, trans and total), TCE and Vinyl chloride were also detected at this well. PCE and TCE (169 ug/L) were the only exceedances to criteria.

Note:Manganese, Dimethylphthalate, and Di-n-butylphthalate did not have criteria available for screening purposes.

Abbreviations:

DCA = Dichloroethane
DCE = Dichloroethene
DCB = Dichlorobenzene
MEK = Methyl ethyl ketone (2-butanone)
MIBK = Methyl isobutyl ketone
PCE = Tetrachloroethene
TCE = Trichloroethene

Table 3.7
Zone 5 Summary of Conditions
Kelly AFB, San Antonio, Texas

Description	North Study Area	South Study Area	West Study Area	East Study Area
Known Source Areas:	IRP site S 1: Storage Area IRP site IS-1: Solvent Still AOC 1500 Area	None	1100 Area	IRP site S-5: Aqua Fuels Area IRP site S-10: Spill Area Base Service Station (B98) Civil Engineering Motor Pool (B38)
Size (acres)	950	770	570	350
Vertical Depth to Water (ft)	15	> 20	20	20
Cover Material	Grass/pavement	Grass/pavement	Grass/pavement	Grass/pavement
Surface Soil Type	Clay/silt	Clay/silt	Clay/silt	Clay/silt
Average Annual Temperature (°F)	69	69	69	69
Estimated Travel Time for Infiltration to Reach the Water Table (yr)	18.8	18.8	25.0	25.0
Prevailing Wind Direction	SE	SE	SE	SE
Average Annual Rainfall (in/yr)	29.1	29.1	29.1	29.1
Recharge/Infiltration Estimate (in/yr)	1 - 3	1 - 3	1 - 3	1 - 3
Average Wind Velocity (mi/hr)	5.8	5.8	5.8	5.8
Fraction Organic Carbon	0.05	0.05	0.05	0.05
Gradient (ft/ft)	.005 - 0.0029	0.0085 - 0.026	0.0042 - 0.026	0.002 - 0.01
Groundwater Flow Velocity (ft/day)	5.0 - 5.8	3.4 - 6.5	0.52 - 1.6	.21 - 3.2
Hydraulic Conductivity (ft/day)	200 - 400	50 - 80	4 - 77	21 - 80
Soil bulk Density (Dry) (g/cm^3)	1.7	1.7	1.7	1.7
Effective Soil Porosity (Above the Water Table)	0.4	0.4	0.4	0.4
Effective Soil Porosity (Below the Water Table)	0.3	0.3	0.3	0.3

TABLE 3.8
Simulated Time (years for the Maximum Concentration to Reach the MCLs at Plume A
Kelly AFB, San Antonio, Texas

	Time to MCL (years)					
	TCE (5 ppb)		DCE (70 ppb)		VC (2 ppb)	
Alternative	**On-Base**	**Off-Base**	**On-Base**	**Off-Base**	**On-Base**	**Off-Base**
Baseline (e.g. MNA)	26	20	13.5	0	29	26
Source-Area Trench	20.5	20	10.5	0	22	26
Perimeter Trench	26	17	13	0	28	18
Perimeter Wells	26	18	13	0	27	18
Off-Base Wells	26	18	13	0	28	20
Source-Area Trench and Perimeter Wells	20	19	10.2	0	21	21
Source-Area Trench, Perimeter Wells, and Off-Base Wells	20	19	10.2	0	21	21

TABLE 3.9
Simulated Time (years) for the Maximum Concentration to Reach the MCLs at Plumes D, H, and J
Kelly AFB, San Antonio, Texas

Plumes	PCE	TCE	DCE	VC
Ambient Conditions (e.g. MNA)				
D	26	28	13.5	26
H	-	6.5	<1	<1
J	6.5	<1	<1	2.5
Pumping Conditions				
D	21	22.5	<1	19
H	-	5	<1	<1
J	5	<1	<1	2

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SECTION 4.0

Development of RAOs and PRGs

4.1 Introduction

RAOs are based on the nature and extent of contamination, risks related to the contamination as identified in the risk assessment, and compliance with federal and State of Texas applicable or relevant and appropriate requirements (ARARs) and risk-based action levels. This section first identifies the ARARs and other TBC materials. The site-specific RAOs are then defined, and PRGs are presented based on the RAOs, ARARs, and the risk-based action levels.

4.2 Applicable or Relevant and Appropriate Requirements

Corrective actions must comply with all applicable laws and regulations. Similarly, Section 121(d)(2)(A) of CERCLA requires that CERCLA response actions achieve compliance with federal and state ARARs. The purpose of these requirements is to make cleanup actions consistent with other pertinent federal and state environmental requirements as well as to adequately protect public health and the environment.

Definitions of ARARs and TBC materials are given below:

- Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that directly and fully address a hazardous substance, pollutant, contaminant, environmental action, location, or other circumstance at a CERCLA site.

- Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not "applicable," address problems or situations sufficiently similar (relevant) to those encountered at a CERCLA site that their use is well suited (appropriate) to the particular site.

- TBC materials are nonpromulgated, nonenforceable guidelines or criteria that may be useful for developing a remedial action or that are necessary for evaluating what is protective to human health and/or the environment. Examples of TBC materials include EPA drinking water health advisories, reference doses, and cancer slope factors.

Tables 4.1 and 4.2 present preliminary State of Texas and federal ARARs, respectively. The ARARs are grouped into three types: chemical-specific, location-specific, and action-specific.

Chemical-specific ARARs include laws and requirements that establish health- or risk-based numerical values or methodologies for environmental contaminant concentrations or discharge. These standards are reflected in the TNRCC Compliance Plan issued to Kelly AFB. Other important chemical-specific ARARs are the federal *Safe Drinking Water Act* (SDWA) MCLs and the State of Texas risk reduction standards, and the State of Texas drinking water standards, surface water discharge standards, and air emission control standards. The risk reduction standards and drinking water standards are important in establishing soil and groundwater PRGs in Sections 4.3 and 4.4. The PRGs are used to evaluate the extent of soil and groundwater remediation required, as well as to estimate the residual levels of contaminants allowable after treatment. The surface water discharge and air emission standards are important in establishing discharge limits for any treatment systems. Surface water discharge standards are provided in Table 4.3, and air emission limits qualifying for a standard exemption from permitting are provided in Table 4.4.

Location-specific ARARs are requirements that relate to the geographical position of the site. State and federal laws and regulations that apply to the protection of wetlands or construction in floodplains are examples of location-specific ARARs. For this remedial action, location-specific ARARs include the state regulation that defines the groundwater under and adjacent to Zone 5 as a potential drinking water source and siting criteria for solid and hazardous waste management facilities.

Action-specific ARARs are requirements for the conduct of certain activities or the operation of certain technologies. The action-specific ARARs most pertinent to this remedial action are federal and state laws pertaining to the management of solid and hazardous waste and state regulations governing wastewater discharges, air emissions, and underground injection.

4.3 Development of Remedial Action Objectives

Based on available data, the soil at Zone 5 does not pose a human health risk with respect to direct exposure to the contaminated soil (CH2M HILL,1999; 1998d). Groundwater contamination resulting from soil leachate at Site S-1 was corrected by the interim actions performed at the site. No further soil issues occue in Zone 5.

Based on the Zone 5 RI (CH2M HILL,1999), the shallow groundwater both on base and off base poses unacceptable risks. These risks are predominantly associated with the potential use of the groundwater as a drinking water supply. There is no known current use of the shallow groundwater aquifer for drinking water, either on base or immediately off base. However, the groundwater is defined as a potential source of drinking water under criteria established by the TNRCC[1]. It is unlikely that on base groundwater will ever be withdrawn directly for use as a drinking water supply, but it still poses risks because it is migrating off base. Based on this, the objectives for groundwater remedial actions for Zone 5 are as follows:

[1] Title 30 of the TAC, Section 335.563(h)(1) states that "Groundwater that has a background total dissolved solids content less than or equal to 10,000 milligrams per liter (mg/L) and that occurs within a geologic zone that is sufficiently permeable to transmit water to a pumping well in usable quantities shall be considered a current or potential source of drinking water for the purpose of determining cleanup levels."

1. Prevent use of on base and off base groundwater that contains contaminants in concentrations exceeding MCLs. Where MCLs are not available, use Texas groundwater MSCs.

2. Reduce or prevent further migration of contaminated groundwater (defined as groundwater with contaminant concentrations that exceed MCLs or, where those are not available, Texas groundwater MSCs) from on base areas to off base areas[2].

3. Restore off base groundwater to MCLs or, where those are not available, to Texas groundwater MSCs, within a reasonable time frame.

4. Restore on base groundwater to MCLs or, where those are not available, to Texas groundwater MSCs, within a reasonable time frame. If that time frame exceeds 20 years, establish alternate concentration limits (ACLs) that are no greater than existing contaminant concentrations and ensure that those ACLs are met during the interim time period.

For purposes of evaluation, this CMS report assumes that contaminated soil at site SS003 (S-1) will be closed under Texas Risk Reduction Rule, Standard 3, and that contaminated groundwater will be closed under Texas Risk Reduction Rule, Standard 2. Meeting remedial action objectives discussed above will achieve the applicable Texas Risk Reduction Standards.

4.4 Preliminary Remediation Goals

Acceptable concentrations for each COC under the relevant exposure settings are identified as PRGs. The contaminant-specific concentration typically is identified by considering risk-based values (1×10^{-4} to 1×10^{-6} excess cancer risk and HI = 1), chemical-specific ARAR values, and background concentrations.

The primary state regulations addressing remedial cleanup standards are the Texas Industrial Waste Management Regulations as presented in TAC Title 30, Part IX, Chapter 335, Subchapter S, "Risk Reduction Standards." The regulations require compliance with one of three possible risk reduction standards. The standards generally can be classified as follows:

- RRS 1: Cleanup of contaminated media to background concentrations.

- RRS 2: Cleanup of contaminated media to health-based standards and criteria. For soil, cleanup is to MSCs. The MSCs are based on achieving an excess lifetime cancer risk of 1×10^{-6} for Class A and Class B carcinogens, 1×10^{-5} for Class C carcinogens, and an HI of 1 for systemic toxicants. Soil MSCs for GWP are either 100 times the residential groundwater cleanup level or a soil concentration that does not produce a leachate in excess of MCLs or MSCs for groundwater. For groundwater under a residential exposure scenario, cleanup is to MCLs, if promulgated, or to MSCs if MCLs are not promulgated. For nonresidential exposure, cleanup is to MCLs, if promulgated. If no MCL has been promulgated, the cleanup level is the MSC multiplied by a factor of 3.36

[2] For purposes of selecting an appropriate remedial action, the term "on base" refers only to those areas of Kelly AFB that will be maintained under federal control following base closure. The term "off base" refers both to those areas that are currently outside the Kelly AFB boundaries and to those areas that will be transferred to a non-federal entity following base closure.

(for carcinogens) or 2.8 (for systemic toxicants). These factors represent differences in exposure parameters between residential and nonresidential groundwater receptors.

- RRS 3: Cleanup of contaminated media to health-based standards and criteria. In general, the medium-specific cleanup standards are based on achieving an excess lifetime cancer risk within a range of 1×10^{-4} to 1×10^{-6} for carcinogens and an HI of 1 for systemic toxicants. The soil MSCs for protection of groundwater may be developed using fate and transport modeling to determine soil concentrations that do not cause exceedance of the groundwater MSCs.

PRGs for groundwater contaminants are presented in Table 4.5. These values are taken from the 30 TAC 335.568, Appendix II table of MSCs, and the TNRCC Compliance Plan for Kelly AFB. These sources are the most pertinent in establishing groundwater cleanup levels. For each contaminant, the more stringent value of the two sources is underlined and constitutes the PRG used in this CMS report for identifying the extent of groundwater to be remediated.

4.5 Contaminated Media Area and Volume Exceeding PRGs

Contaminant concentrations in groundwater were compared against the PRGs to determine the areal extent requiring remediation. The areal extent of groundwater contamination in Zone 5 is shown via plume maps for each COC that are presented in Figures 3.5 to 3.11. Each of those maps delineates that portion of the plume(s) that exceeds the PRG (either the MCL or MSC) for the given COC. The reference figures are Figure 3.5 (arsenic), Figure 3.6 (TCE), Figure 3.7 (PCE), Figure 3.8 (total 1,2-DCE), Figure 3.9 (cis-1,2-DCE), Figure 3.10 (benzene), and Figure 3.11 (CB).

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TABLE 4.1
State of Texas Applicable or Relevant and Appropriate Requirements for Remedial Action at Zone 5
Kelly AFB, San Antonio, Texas

ARAR Citation	Requirement	Rationale for Use	Type of Requirement
Chemical-Specific			
Texas Drinking Water Standards (30 TAC Chapter 290, Water Hygiene, Subchapter F)	Establishes bacteriological, chemical, and radiological quality criteria for public drinking water in compliance with Public Law 93-523, the Federal Safe Drinking Water Act, and Primary Drinking Water Regulations of EPA. Standards of quality (MCL) for specific chemicals are listed in 30 TAC 290.103.	There is no current use of the shallow groundwater under or adjacent to Zone 5 for public consumption, however, the aquifer qualifies as a potential source of drinking water. Under Texas Risk Reduction Standards (30 TAC 335 Subchapter S), drinking water standards are cleanup criteria for groundwater that is a current or potential drinking water source.	Potentially relevant and appropriate
Texas Surface Water Quality Standards (30 TAC Chapter 307)	Lists general criteria (307.4) and establishes criteria for specific toxic substances (307.6) to maintain the quality of water in the state. Specific standards are provided in Table 4.3 of this CMS.	Groundwater might be extracted, treated, and discharged to Leon Creek, which is classified as a water of the state.	Potentially applicable
TNRCC Permit No. 03955	Establishes limits and criteria for discharges of treated groundwater from Kelly AFB to adjacent surface waters. Specific limits are provided in Table 4.3.	Treated groundwater might be discharged to permitted outfalls.	TBC
Hazardous Metals (30 TAC Chapter 319, General Regulations Incorporated into Permits, Subchapter B)	Establishes allowable concentrations for discharge of hazardous metals to inland waters (319.22). Specific standards are provided in Table 4.3 of this CMS. Standards may be used, where necessary, for GWP (319.27).	Hazardous metals have been detected in the Zone 5 groundwater and the groundwater may be extracted, treated, and discharged to waters of the state. May be pertinent in establishing groundwater cleanup levels for hazardous metals at Zone 5.	Potentially applicable Potentially relevant and appropriate

TABLE 4.1
State of Texas Applicable or Relevant and Appropriate Requirements for Remedial Action at Zone 5
Kelly AFB, San Antonio, Texas

ARAR Citation	Requirement	Rationale for Use	Type of Requirement
Chemical Specific (continued)			
Discharge to Surface Waters from Treatment of Petroleum Substance Contaminated Waters (30 TAC Chapter 321, Control of Certain Activities by Rule, Subchapter H)	Establishes allowable concentrations for discharge of petroleum-related contaminants. Requirements include the following: Parameter — Limitation Lead — 0.25 mg/L TPH — 15 mg/L Benzene — 0.050 mg/L Total BTEX — 0.5 mg/L	Benzene has been detected in the site S-1 groundwater. Requirements may be relevant and appropriate in establishing cleanup levels and/or developing treated effluent discharge requirements if contaminated groundwater is collected as part of dewatering or otherwise extracted.	Potentially relevant and appropriate
Texas Industrial Solid Waste and Municipal Hazardous Waste (30 TAC Chapter 335)	Establishes the basic framework for state regulation of solid and hazardous waste.	Solid/hazardous waste might be generated as part of remedial actions.	Potentially applicable
Subchapter R, Waste Classification	Contains numerical criteria for designating a waste as a hazardous waste or as one of three classes of solid waste.	Soil, groundwater, or secondary waste generated as part of remedial actions might designate as hazardous waste depending on concentrations.	Potentially applicable
Subchapter F, Permitting Standards for Owners and Operators of Hazardous Waste Storage, Processing, or Disposal Facilities	Establishes GWP standards for permitted hazardous waste facilities, including standards for 14 toxic compounds that are equal to MCLs under the *Safe Drinking Water Act* (30 TAC 335.160). Provides a method for establishing ACL for groundwater (335.160(b)). Specifies process for establishing groundwater background concentrations. Establishes groundwater cleanup standards.	Pertinent to developing remediation goals and monitoring requirements for solid waste management units (SWMUs). Development of ACLs might be pertinent for on base groundwater.	Relevant and appropriate
Subchapter S, Risk Reduction Rules	Establishes a three-tiered cleanup program for releases from SWMUs with different numerical cleanup standards for each tier. Standard 1 is cleanup to background concentrations. Standards 2 and 3 set cleanup levels for groundwater at MCLs (if available), and identify methods for calculating MSCs for soil and for groundwater where MCLs are not available.	Some contamination in Zone 5 resulted from releases from designated SWMUs. Other contamination in Zone 5 is essentially similar to contamination from SWMUs.	Applicable for designated SWMUs. Relevant and appropriate for all cleanup in Zone 5.

TABLE 4.1
State of Texas Applicable or Relevant and Appropriate Requirements for Remedial Action at Zone 5
Kelly AFB, San Antonio, Texas

ARAR Citation	Requirement	Rationale for Use	Type of Requirement
Location-Specific			
Texas Surface Water Quality Standards (30 TAC Chapter 307)	Appendix C defines classification categories for specific segments of surface waters in the state.	Groundwater might be extracted, treated, and discharged to Lower Leon Creek (Waterbody Segment Code No. 1906 of the San Antonio River Basin).	Potentially applicable
Location Standards for Hazardous Waste Storage, Processing, or Disposal (30 TAC Chapter 335, Texas Industrial Solid Waste and Municipal Hazardous Waste, Subchapter G)	Establishes minimum standards for the location of facilities used to store, process, treat, or dispose of hazardous waste. Does not apply to on-site remedial actions conducted pursuant to CERCLA or the Texas Solid Waste Disposal Act (30 TAC 335.201(a)(3)).	Although hazardous waste facilities might be sited as part of remedial action, the regulation excludes CERCLA cleanups from the standards.	Not applicable
Risk Reduction Standards (30 TAC Chapter 355, Texas Industrial Solid Waste and Municipal Hazardous Waste, Subchapter S)	30 TAC 335.563(h)(1) defines groundwater that is a potential current or future source of drinking water for purposes of cleanup under the Risk Reduction Rules. The criteria are primarily total dissolved solids and permeability/pumpability.	Groundwater at Zone 5 meets the definition of a potential source of drinking water.	Applicable for designated SWMUs. Relevant and appropriate for all cleanup in Zone 5.
Action-Specific			
Exemptions from Permitting (30 TAC Chapter 106)	Establishes criteria for Standard Exemptions under which certain facilities or types of facilities do not require air permits.	Remedial actions might generate air emissions.	Potentially applicable
Subchapter X, Waste Processes and Remediation	Per 30 TAC 106.533, water and soil remediation projects are exempt from air permitting if: 10. Emissions are less than specified in 30 TAC 106.262 (see Table 4.4) 11. There are no visible emissions 12. If abatement equipment is used to meet emissions limits, it satisfies conditions for direct-flame combustion, flares, catalytic oxidizers, or carbon adsorption as specified in the regulation.	Remedial actions may qualify for the permitting exemption if they meet the requirements of the exemption.	Potentially applicable
Consolidated Permits (30 TAC Chapter 305)	Establishes standards and requirements for management of waste disposal activities. Includes wastewater discharge permits, solid waste permits, and injection well permits.	Remedial actions might involve wastewater discharges, management/processing of solid or hazardous waste, and/or reinjection of treated groundwater.	Potentially applicable

TABLE 4.1
State of Texas Applicable or Relevant and Appropriate Requirements for Remedial Action at Zone 5
Kelly AFB, San Antonio, Texas

ARAR Citation	Requirement	Rationale for Use	Type of Requirement
Texas Surface Water Quality Standards (30 TAC Chapter 307)	Establishes permitting process for discharges to waters of the state. Existing permit addresses discharge of treated groundwater.	Groundwater might be extracted, treated, and discharged to Leon Creek, which is classified as a water of the state.	Potentially applicable
TNRCC Permit No. 03955	Authorizes discharge of treated groundwater from Kelly AFB to adjacent surface waters.	Treated groundwater might be discharged to permitted outfalls discharging to Leon Creek.	TBC
Control of Air Pollution From Visible Emissions and Particulate Matter (30 TAC Chapter 111)	Establishes requirements and standards for activities that could produce visible and particulate emissions.	Remedial actions might release particulate into the air.	Potentially applicable
Control of Air Pollution from Toxic Materials (30 TAC Chapter 113)	Establishes specific limits and requirements for activities that could produce emissions of toxic materials. Currently only addresses beryllium and lead, but it is anticipated that other toxic materials will be added in the future.	Remedial actions might release contaminants into the air that could eventually fall under this regulation.	Potentially applicable
Control of Air Pollution from Volatile Organic Compounds (30 TAC Chapter 115)	Requires control devices for activities that would involve tank storage of VOCs.	Zone 5 contaminants include VOCs; remedial actions might involve storage of storage of VOC-contaminated groundwater.	Potentially applicable
Control of Air Pollution by Permits for New Construction or Modification (30 TAC Chapter 116)	Requires a permit for construction or modification of any facility that may emit contaminants into the air, unless the facility meets the requirements for a standard exemption under 30 TAC 106.	Remedial actions may include construction or expansion of facilities that may emit contaminants into the air, but it is anticipated that the release will qualify for a standard exemption.	Applicable only if the action does not qualify for a standard exemption
Waste Disposal Approvals, Review, and Approval of Plans and Specifications for Disposal (30 TAC Chapter 323)	Requires submittal of plans and specifications for construction and operation of treatment facilities.	Remedial actions might involve construction/expansion of one or more treatment facilities.	Potentially applicable

TABLE 4.1
State of Texas Applicable or Relevant and Appropriate Requirements for Remedial Action at Zone 5
Kelly AFB, San Antonio, Texas

ARAR Citation	Requirement	Rationale for Use	Type of Requirement
Action-Specific (continued)			
Underground Injection Control (30 TAC Chapter 331)	Establishes requirements and prohibitions related to underground injection of fluids. Generally prohibits injection of hazardous fluids, except that wells used to inject hazardous-waste contaminated groundwater that is of acceptable quality to aid remediation an that is reinjected into the same formation from which it was drawn is not prohibited (30 TAC 331.6). Injection wells must be registered with the state.	Effluent from the treatment of groundwater may be injected into the same formation from which it was collected.	Potentially applicable, although injection is not a likely remedial alternative.
Industrial Solid Waste and Municipal Hazardous Waste (30 TAC Chapter 335)	Establishes the basic framework for state regulation of solid and hazardous waste.	Solid and/or hazardous waste might be generated, stored, processed, and/or disposed as part of remedial actions.	Potentially applicable
Subchapter A, Industrial Solid Waste and Municipal Hazardous Waste in General	Establishes process for closure and remediation of contaminated media resulting from unauthorized discharge of industrial solid waste or municipal hazardous waste (30 TAC 335.8).	Corrective action is being undertaken in Zone 5 to address unauthorized releases of industrial solid wastes. Kelly AFB is an industrial solid waste management facility subject to such corrective action.	Applicable
Subchapter B, Hazardous Waste Management General Provisions	Defines when a permit is required for activities involving industrial solid waste and municipal hazardous waste. Excludes wastewater treatment units that are subject to Clean Water Act permitting and that meet the definition of a tank or tank system from Subchapters E and F.	Extracted groundwater and/or excavated soil might designate as hazardous waste, and storage/treatment/disposal would require permitting, except that if groundwater is treated in a wastewater treatment unit and discharged under an NPDES permit, no hazardous waste permit will be required.	Potentially applicable
Subchapters C, D, and F, Standards Applicable to Generators and Transporters of Hazardous Waste, Facilities Storing, Processing, or Disposing Hazardous Waste	Establishes detailed requirements (e.g., labeling, containment, permitting) for the management, storage, processing, and disposal of hazardous waste. The TNRCC Compliance Plan issued in accordance with Subchapter F requires specific actions related to groundwater remediation.	The TNRCC Compliance Plan specifically addresses SWMUs in Zone 5 that are also IRP sites addressed in this CMS. Extracted groundwater, excavated soil, and/or secondary wastes from remedial actions might designate as hazardous waste. During remedial action, these materials might be stored, processed, or disposed.	Applicable

TABLE 4.1
State of Texas Applicable or Relevant and Appropriate Requirements for Remedial Action at Zone 5
Kelly AFB, San Antonio, Texas

ARAR Citation	Requirement	Rationale for Use	Type of Requirement
Subchapter S, Risk Reduction Rules	Establishes administrative process for remediating SWMUs and releases to environmental media from those units.	Contamination in Zone 5 resulted in part from releases from SWMUs and thus is subject to the remediation process described in the Rules.	Applicable
Subchapter O, Land Disposal Restrictions	Restricts placement/land disposal of certain listed or characteristic hazardous waste without treatment. Identifies treatment standards and Best Demonstrated Available Technology.	Extracted groundwater and/or secondary waste might be designated as hazardous waste and would thus require treatment before placement or disposal.	Potentially applicable
Oil and Hazardous Substances (30 TAC Chapter 343)	Provides permitting exemption for emergency control, containment, removal, and disposal of oil or hazardous substances spills or discharges, if delay caused by obtaining permits from TNRCC would endanger health or the environment.	Pertinent only if delay in remedial action necessitated by obtaining commission authorization would endanger health or the environment.	Potentially applicable

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Table 4.2
Federal Applicable or Relevant and Appropriate Requirements for Remedial Action at Zone 5
Kelly AFB, San Antonio, Texas

ARAR Citation	Requirement	Rationale for Use	Type of Requirement
Chemical-Specific			
Federal Water Pollution Control Act (FWPCA), as amended by the Clean Water Act of 1977 (CAA) (33 U.S.C. 1251 et seq.)	Creates the basic national framework for water pollution control and water quality management.	The remedial action will address groundwater contamination.	Applicable
Designation of Hazardous Substances (40 *Code of Federal Regulations* [CFR] 116)	Designates hazardous substances in Tables 116.4A and 116.4B of the regulation.	Designated hazardous substances are present in the soil and groundwater at Zone 5.	Applicable
National Pollutant Discharge Elimination System (NPDES) (40 CFR 122)	Establishes standards for discharges to surface waters of the United States.	Treated groundwater might be discharged to nearby surface waters. The standards would be pertinent in developing goals for treatment and discharge, if the discharge is not addressed under existing permits.	Applicable if treated groundwater discharged to a surface water
NPDES Permit No. TX0116114	Establishes specific limits and criteria for discharges of treated groundwater from Kelly AFB to adjacent surface waters.	Treated groundwater might be discharged to outfalls covered by the permit.	TBC
Safe Drinking Water Act (42 U.S.C. 300 f et seq.)	Creates a comprehensive national framework to ensure the quality and safety of drinking water.	Shallow groundwater under and adjacent to Zone 5 is not currently withdrawn for public consumption, however, it qualifies as a potential source of drinking water.	Relevant and appropriate
National Primary Drinking Water Regulations (40 CFR 141)	Establishes MCLs and maximum contaminant level goals for organic, inorganic, and radioactive constituents in public water systems serving at least 25 persons.	Shallow groundwater under and adjacent to Zone 5 is not currently withdrawn for public consumption, however, it qualifies as a potential source of drinking water. Under Texas Risk Reduction Rules (30 TAC 355 Subchapter S), MCLs are cleanup criteria for groundwater that is a current or potential drinking water source. Also, treated groundwater may be injected into the shallow aquifer, which qualifies as a potential drinking water source.	Relevant and appropriate

Table 4.2
Federal Applicable or Relevant and Appropriate Requirements for Remedial Action at Zone 5
Kelly AFB, San Antonio, Texas

ARAR Citation	Requirement	Rationale for Use	Type of Requirement
Chemical-Specific (continued)			
National Secondary Drinking Water Regulations (40 CFR 143)	Sets secondary maximum contaminant levels (SMCLs) for contaminants in drinking water that primarily affect the aesthetic qualities relating to the public acceptance of drinking water.	Treated groundwater may be injected into the shallow aquifer, which qualifies as a potential source of drinking water.	Potentially relevant and appropriate
Solid Waste Disposal Act (SDWA), as amended by the Resource Conservation and Recovery Act (42 U.S.C. 6901 et seq.)	Establishes the basic framework for federal regulation of solid and hazardous waste including specific chemical criteria. Authority for implementation has been delegated, in part, to the state.	Solid/hazardous waste was previously disposed at Zone 5. In addition, waste might be generated as part of the remedial action.	Applicable
Identification and Listing of Hazardous Waste (40 CFR 261)	Contains numerical criteria for designating a waste as a hazardous waste.	Authority to implement these requirements has been delegated to the state. See 30 TAC 355 in Table 4.1.	NA
Groundwater Protection and Monitoring (40 CFR 264.90-264.109)	Establishes requirements for SWMUs. Specifies GWP standards for 14 toxic compounds that are equal to MCLs under the Safe Drinking Water Act.	Authority to implement these requirements has been delegated to the state. See 30 TAC 355 in Table 4.1.	NA
Land Disposal Restrictions (40 CFR 268)	Provides numerical treatment standards for land disposal of some hazardous wastes.	Hazardous waste generated during remedial action must be treated to meet standards prior to disposal.	Potentially applicable
Corrective Action at SWMUs (40 CFR Subpart S (proposed))	Includes specific cleanup standards for releases from SWMUs.	Pertinent in developing remediation goals and monitoring requirements for Zone 5 soil and groundwater.	TBC
Clean Air Act (CAA), as amended (42 U.S.C. 7401 et seq.)	Establishes the basic framework for federal regulation of any activities that affect air quality.	Remedial action might result in airborne emissions.	Potentially applicable
National Emissions Standards for Hazardous Air Pollutants (NESHAPS) (40 CFR 61)	Contains standards for significant sources of hazardous air pollutants such as vinyl chloride and benzene. Standards are also for sources that have the potential to emit 10 tons of any single hazardous air pollutant or 25 tons of all pollutants/year.	Remedial actions might result in the release of hazardous air pollutants. Control equipment might have to be factored into treatment system design.	Potentially applicable

Table 4.2

Federal Applicable or Relevant and Appropriate Requirements for Remedial Action at Zone 5

Kelly AFB, San Antonio, Texas

ARAR Citation	Requirement	Rationale for Use	Type of Requirement
Chemical-Specific (continued)			
Reference Doses (RfDs), EPA Office of Research and Development	Presents nonenforceable toxicity data for specific chemicals for use in public health assessments.	Standard used to assess risk associated with soil and groundwater.	TBC
Risk Specific Doses (RSDs), EPA Carcinogen Assessment Group and EPA Environmental Criteria and Assessment Office	Represents the dose of a chemical in mg per kg of body weight per day associated with a specific risk level (i.e., 10^{-6}). RSDs are determined by dividing the selected risk level by the cancer potency factor (slope factor).	Standard used to assess risk associated with soil and groundwater.	TBC
Health Advisories, EPA Office of Drinking Water	Nonenforceable contaminant limits for chemicals that may be intermittently encountered in public water supply systems. Available for short- or long-term exposures for a child and/or adult.	Pertinent in developing remediation goals for groundwater, particularly when MCLs are not established for a contaminant.	TBC
Location-Specific			
Historic Sites, Buildings, and Antiquities Act (16 U.S.C. 461)	Establishes requirements for the preservation or historic sites, buildings, or objects of national significance. Undesirable impacts to such resources must be mitigated.	Buildings of historic or national significance may be present at Kelly AFB.	Potentially applicable
SDWA, as amended RCRA (42 U.S.C. 6901 et seq.)	Establishes the basic framework for federal regulation of solid and hazardous waste.	Solid/hazardous waste might be managed as part of the remedial action.	Applicable
Criteria for Classification of Solid Waste Disposal Facilities and Practices (40 CFR 257)	Establishes criteria based in part on location (such as floodplains, impacted surface waters) to determine which solid waste disposal facilities pose a probability of adverse effects on health or the environment.	Onsite treatment or offsite disposal of solid wastes might occur as part of remediation.	Potentially applicable
Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (40 CFR 264)	Establishes location standards for hazardous waste management facilities.	Authority to implement these requirements has been delegated to the state. See 30 TAC 355 in Table 4.1.	NA
Action-Specific			
Occupational Safety and Health Administration (OSHA) Requirements (29 CFR 1910, 1926, and 1904)	Establishes requirements for occupational health and safety applicable to workers engaged in hazardous waste site or CERCLA response actions.	Required for workers who will be exposed to hazardous substances during remediation activities.	Applicable

Table 4.2
Federal Applicable or Relevant and Appropriate Requirements for Remedial Action at Zone 5
Kelly AFB, San Antonio, Texas

ARAR Citation	Requirement	Rationale for Use	Type of Requirement
DOT Rules for Hazardous Materials Transport (49 CFR 107, 171.1-500)	Establishes requirements for the transport of hazardous materials including packaging, shipping, and placarding.	Remedial actions might include off base transportation of hazardous materials for treatment and/or disposal.	Potentially applicable
SDWA, as amended by the RCRA (42 U.S.C. 6901 et seq.)	Establishes the basic framework for federal regulation of solid and hazardous waste, including specific requirements related to waste activities. Subpart C of RCRA controls the generation, transportation, treatment, storage, and disposal of hazardous waste through a comprehensive “cradle to grave” system of hazardous waste management requirements.	Solid/hazardous waste might be managed as part of the remedial action.	Applicable
Identification and Listing of Hazardous Waste (40 CFR 261)	Provides methodology for determining whether a material is a hazardous waste.	Authority to implement these requirements has been delegated to the state. See 30 TAC 355 in Table 4.1.	NA
Standards for Generators and Transporters of Hazardous Waste and Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (40 CFR 262-265, and 266)	Establishes detailed requirements related to generation and management of hazardous waste.	Authority to implement these requirements has been delegated to the state. See 30 TAC 355 in Table 4.1.	NA
Land Disposal Restrictions (40 CFR 268)	Restricts certain hazardous wastes from placement or disposal on land without treatment.	Soil or secondary wastes from remedial actions that designate as hazardous waste must be treated prior to disposal.	Potentially applicable
Action-Specific (continued)			
Corrective Action for Solid Waste Management Units at Hazardous Waste Management Facilities; Proposed Rule (RCRA Subpart S) (40 CFR 264, 265, 270, and 271)	Establishes a process for remediating SWMUs regulated under RCRA.	Some sites within Zone 5 are identified as SWMUs.	TBC
FWPCA, as amended by the CWA (33 U.S.C. 1251 et seq.)	Creates the basic national framework for water pollution control and water quality management in the United States.	The remedial action will address groundwater contamination.	Applicable
National Pollutant Discharge Elimination System (NPDES) Requirements (40 CFR 122)	Establishes a system to regulate point-source discharges to dredge or fill material, and oil and hazardous waste spills to U.S. waters.	Remedial actions might involve discharging treated groundwater to waters of the U.S.	Potentially applicable

Table 4.2

Federal Applicable or Relevant and Appropriate Requirements for Remedial Action at Zone 5

Kelly AFB, San Antonio, Texas

ARAR Citation	Requirement	Rationale for Use	Type of Requirement
General Pretreatment Regulations for Existing and New Sources of Pollutants (40 CFR 403)	Establishes a system to regulate effluent discharges to publicly-owned treatment works (POTW).	Remedial actions might involve discharging treated groundwater to a sanitary sewer directed to the local POTW.	Potentially applicable
Safe Drinking Water Act (42 U.S.C. 300 f et seq.)	Creates a comprehensive national framework to ensure the quality and safety of drinking water.	Shallow groundwater under and adjacent to Zone 5 is not currently withdrawn for public consumption; however, it qualifies as a potential source of drinking water.	Relevant and appropriate
Underground Injection Control Program (40 CFR 144, 147)	Ensures that underground injection of fluids will not endanger drinking water sources by violating MCLs or by adversely affecting health.	Treated groundwater might be injected into the shallow aquifer.	Potentially applicable, although injection is not a likely remedial alternative.
Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites (U.S. EPA Office of Solid Waste and Emergency Response Directive 9200.4-17)	Clarifies EPA's policy regarding the use of monitored natural attenuation for the remediation of contaminated soil and groundwater.	Natural attenuation might be appropriate for use in groundwater remediation at Zone 5.	TBC

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TABLE 4.3
Surface Water Discharge Standards
Kelly AFB, San Antonio, Texas

Chemicals Identified as COPCs	TNRCC Wastewater Discharge Permit No. 03955, Outfall 001 (mg/L)			NPDES Discharge Permit No. TX0116114, Outfall 001 (mg/L)		TNRCC Quality Levels for Hazardous Metals (30 TAC 319.22) (mg/L)
	Daily Avg	Daily Max	Single Grab	Daily Avg	Daily Max	Average Composite
VOCs						
Benzene	2.7e-02	5.8e-02	8.7e-02	1.0e-02	1.1e-02	
Butylbenzene, sec-	a.	a.	a.	a.	a.	
Butylbenzene, tert-	a.	a.	a.	a.	a.	
Chlorobenzene	1.42e-01	3.8e-01	5.7e-01	N/A	5.0e-02	
Chloroethane	a.	a.	a.	a.	a.	
Dichloroethane, 1,1-	2.2e-02	5.9e-02	8.9e-02	N/A	5.9e-02	
Dichloroethene, 1,1-	2.2e-02	6.0e-02	9.0e-02	1.0e-02	1.6e-02	
Dichloroethene, cis- 1,2-	a.	a.	a.	a.	a.	
Dichloroethene, total 1,2-	2.5e-02	5.8e-02	8.7e-02	N/A	5.4e-02	
Dichloropropene, 1,1-	a.	a.	a.	a.	a.	
Ethylbenzene	1.42e-01	3.8e-01	5.7e-01	N/A	1.08e-01	
Isopropylbenzene	a.	a.	a.	a.	a.	
n-propylbenzene	a.	a.	a.	a.	a.	
Tetrachloroethene	2.7e-02	5.8e-02	8.7e-02	N/A	5.4e-02	
Toluene	2.8e-02	7.4e-02	1.11e-01	N/A	8.0e-02	
Trichloroethane, 1,1,1-	2.2e-02	5.9e-02	8.9e-02	N/A	5.4e-02	
Trichoroethene	2.6e-02	6.9e-02	1.04e-01	1.0e-02	1.1e-02	
Vinyl chloride	1.1e-02	2.3e-02	3.5e-02	1.0e-02	1.0e-02	
Xylene, mixture	a.	a.	a.	2.1e-02	5.2e-02	
Semivolatile Organic Compounds (SVOCs)						
Bromacil	a.	a.	a.	a.	a.	
Bromomethane	a.	a.	a.	a.	a.	
Dichlorobenzene, 1,2-	5.0e-02	1.06e-01	1.59e-01	N/A	1.63e-01	
Dichlorobenzene, 1,3-	1.05e-01	2.22e-01	3.33e-01	N/A	4.4e-02	
Dichlorobenzene, 1,4-	a.	a.	a.	N/A	2.8e-02	
Methylnaphthalene, 2-	2.7e-02	5.8e-02	8.7e-02	N/A	Report	
						CONTINUED
Metals						
Arsenic	a.	a.	a.	a.	a.	2.0e-01

TABLE 4.3
Surface Water Discharge Standards
Kelly AFB, San Antonio, Texas

Chemicals Identified as COPCs	TNRCC Wastewater Discharge Permit No. 03955, Outfall 001 (mg/L)			NPDES Discharge Permit No. TX0116114, Outfall 001 (mg/L)		TNRCC Quality Levels for Hazardous Metals (30 TAC 319.22) (mg/L)
	Daily Avg	Daily Max	Single Grab	Daily Avg	Daily Max	Average Composite
Barium	a.	a.	a.	a.	a.	2.0e+00
Chromium, hexavalent	1.4e-02	2.9e-02	4.4e-02	1.4e-02	2.9e-02	a.
Chromium, total	a.	a.	a.	a.	a.	1.0e+00
Cobalt	a.	a.	a.	a.	a.	a.
Iron	a.	a.	a.	1.0e+00	2.0e+00	a.
Lead	a.	a.	a.	a.	a.	1.0e+00
Manganese	2.73e-01	5.79e-01	8.69e-01	5.0e-01	1.0e+00	2.0e+00
Nickel	a.	a.	a.	a.	a.	2.0e+00
Vanadium	a.	a.	a.	a.	a.	a.
Zinc	a.	a.	a.	a.	a.	2.0e+00

NA = not applicable

a. Constituent not identified in permit or regulation.

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TABLE 4.4
Air Emission Limits Qualifying for a Standard Exemption from Permitting Under 30 TAC 106 for COCs
Kelly AFB, San Antonio, Texas

Contaminant of Concern	L (mg/cubic meter)	E (lb/hr) at 100 ft	E (lb/hr) at 200 ft	E (lb/hr) at 300 ft
Arsenic	0.01 (a)	3.07E-05	5.00E-05	7.19E-05
Trichloroethene	135 (a)	0.414	0.675	0.971
Tetrachloroethene	33.5 (a)	0.103	0.168	0.241
Total 1,2-dichloroethene	180 (a)	0.552	0.900	1.29
Cis 1,2-dichloroethene	793 (b)	2.43	3.97	5.71
Benzene	3 (a)	9.20E-03	1.50E-02	2.16E-02
Chlorobenzene	345 (b)	1.06	1.73	2.48

Maximum allowable hourly emission measured at the point of emission (E) = L/K where K depends on the distance from the point of emission to the facility boundary.

Distance	K
100 ft	326
200 ft	200
300 ft	139

a. From 30 TAC 106.262, Table 262.

b. Time weighted average threshold limit value (TLV) published by the American Conference of Governmental Industrial Hygienists (ACGIH, 1985-1986 edition).

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TABLE 4.5
Groundwater Preliminary Remediation Goals
Kelly AFB, San Antonio, Texas

Chemicals Identified as COPCs	TAC Risk Reduction Standard 2, Appendix II MSCs (mg/L) Groundwater Residential Exposure[a.]	TNRCC Compliance Plan (mg/L)[b.]
VOCs		
Benzene	5.00e-03	5.00e-03
Butylbenzene, sec-	c.	d.
Butylbenzene, tert-	c.	d.
Chlorobenzene	1.00e-01	1.00e-01
Chloroethane	7.30e-01	7.30e-01
Dichloroethane, 1,1-	3.65e+00	3.65e+00
Dichloroethene, 1,1-	7.00e-03	7.00e-03
Dichloroethene, cis- 1,2-	7.00e-02	d.
Dichloroethene, total 1,2-	c.	7.00e-02
Dichloropropene, 1,1-	c.	d.
Ethylbenzene	7.00e-01	7.00e-01
Isopropylbenzene	c.	d.
n-propylbenzene	c.	d.
Tetrachloroethene	5.00e-03	5.00e-03
Toluene	1.00e+00	1.00e+00
Trichloroethane, 1,1,1-	2.00e-01	2.00e-01
Trichloroethene	5.00e-03	5.00e-03
Vinyl chloride	2.00e-03	2.00e-03
Xylene, mixture	1.00e+01	1.00e+01
Semivolatile Organic Compounds (SVOCs)		
Bromacil	c.	d.
Bromomethane	5.11e-02	d.
Dichlorobenzene, 1,2-	6.00e-01	6.00e-01
Dichlorobenzene, 1,3-	6.00e-01	6.00e-01
Dichlorobenzene, 1,4-	7.50e-02	7.50e-02
Methylnaphthalene, 2-	c.	d.
Metals		
Arsenic	5.00e-02	5.00e-02
Barium	2.00e+00	2.00e+00
Chromium, total	1.00e-01	1.00e-01
Cobalt	c.	9.4e-01
Iron	c.	d.
Lead	1.5e-02	1.5e-02
Manganese	c.	d.
Nickel	1.00e-01	1.00e-01
Vanadium	c.	1.1e-01
Zinc	c.	5.0e+00

TABLE 4.5
Groundwater Preliminary Remediation Goals
Kelly AFB, San Antonio, Texas

Chemicals Identified as COPCs	TAC Risk Reduction Standard 2, Appendix II MSCs (mg/L) Groundwater Residential Exposure[a.]	TNRCC Compliance Plan (mg/L)[b.]

Value underlined represents the most restrictive PRG.

a. From 30 TAC 335.568, Appendix II, revised as of September 23, 1999.

b. TNRCC Compliance Plan values were based on TAC Risk Reduction Standard 2, current as of the date the plan was issued (June 12, 1998).

c. PRG not available. Value not presented in 30 TAC 335.568, Appendix II.

d. No value provided.

SECTION 5.0

Identification and Screening of Technology Types and Process Options

5.1 General Response Actions for Groundwater

General response actions (GRAs) were selected to satisfy the RAOs and PRGs outlined in Section 4.0 by either reducing concentrations of hazardous substances or by reducing the likelihood of contact with hazardous substances. They include actions such as treatment, containment, collection, disposal, and institutional controls. Although one response action may meet the goals, a combination of response actions may meet the goals more effectively. The integration of response actions into the overall remedial alternatives is presented in Section 6.0.

The GRAs identified for the groundwater media at Zone 5 are as follows:

- No action
- Monitored natural attenuation
- Monitoring
- Institutional controls
- Containment
- In situ treatment
- Ex situ treatment
- Discharge.

These GRAs are summarized below:

- No action consists of taking no further action with respect to the groundwater at Zone 5. The No Action Alternative is required by NCP to provide a baseline for comparison of the other alternatives.
- Monitored natural attenuation consists of processes that, without direct human effort, effectively reduce contaminant toxicity, mobility, or volume (TMV). Examples include biodegradation, dispersion, dilution, sorption, and volatilization.
- Monitoring consists of collecting and evaluating data to support remedial activities. Examples include groundwater monitoring to show the success of hydraulic control or to demonstrate natural attenuation.
- Institutional controls are administrative or physical measures implemented to restrict contact with the groundwater. Examples include deed restrictions and fences. Certain

institutional controls can be implemented by authorities at Kelly AFB, while others rely on federal, state, or local agencies.

- Containment consists of measures to control the movement of contaminants and includes subsurface low permeability barriers or hydrodynamic controls to contain the contaminants within a given area. Slurry walls and extraction wells are examples of a containment technology.
- In situ treatment consists of a variety of treatment technologies that are applied in the subsurface groundwater. Examples include biological degradation and reactive permeable treatment walls.
- Ex situ treatment consists of treating groundwater above ground once it has been extracted. Examples include air stripping and biological treatment.
- Discharge of treated or untreated groundwater. Examples include discharge to a surface water and injection to the aquifer.

5.2 Identification and Screening of Technology Types and Process Options for Groundwater

In this section, the technology types and process options available for remediation of groundwater are presented and screened for suitability. The purpose of this step is to screen the technologies that are clearly not applicable for remediation. An inventory of technology types and process options is presented based on professional experience; published sources, the Remediation Technologies Screening Matrix and Reference Guide (FRTR, 1998), computer databases, and other available documentation for the GRAs identified in Section 5.1. This step may eliminate a GRA from the CMS process if there are no feasible technologies identified for that GRA. The objective, however, is to retain the best technology types and process options within each GRA and use them for developing remedial alternatives.

Figures 5.1 present the screening summary for groundwater remediation. The figure presents the primary and secondary screening results for the technology types and process options considered. Shaded boxes indicate process options that failed to pass the screening (either primary or secondary). Each technology type and process option that is retained is either a demonstrated, proven process, or a potential process that has undergone laboratory trials or bench-scale testing. The factors included in this evaluation include the following: the state of technology development, site conditions, waste characteristics, the nature and extent of contamination, and the presence of constituents that could limit the effectiveness of the technology. Entire technologies and individual process options are screened from further consideration based on technical implementability. Process options that failed the primary screening have a comment in the "Technical Implementability" column of Figure 5.2 explaining why the option failed to pass the primary screening.

Technologies and process options retained after the primary screening are further evaluated using a qualitative comparison based on effectiveness, implementability, and cost. The secondary screening evaluations for groundwater remediation are presented in Sections 5.2.1.2. The process options that were screened out during secondary screening have a

comment with a brief reason under the "Secondary Screening" heading in Figure 5.2. Following this qualitative screening, those remedial technology types and process options that are considered viable for remediating the groundwater at the site are carried forward for incorporation into alternatives.

As mentioned above, technology types and process options are screened in an evaluation process based on effectiveness, implementability, and cost. Effectiveness is considered the ability of the process option to perform as part of a comprehensive remedial plan to meet RAOs under the conditions and limitations present at the site. Additionally, the NCP defines effectiveness as the "degree to which an alternative reduces TMV through treatment, minimizes residual risk, affords long-term protection, complies with ARARs, minimizes short-term impacts, and how quickly it achieves protection." This is a relative measure for comparison of process options that perform the same or similar functions. Implementability refers to the relative degree of difficulty anticipated in implementing a particular process option under the regulatory, technical, and schedule constraints posed. At this point, the cost criterion is only comparative and, like the effectiveness criterion, it is used to eliminate further evaluation of process options that are very costly if there are other choices that perform similar functions with similar effectiveness. The cost criterion includes construction costs and any long-term costs to operate and maintain technologies that are part of an alternative. The NCP preference is for solutions that utilize treatment technologies to permanently reduce the TMV of hazardous substances. Available treatment processes typically are divided into three technology types—physical/chemical, biological, and thermal—that are applied in one or more GRAs with varying results. The technology types and process options identified in the following sections are those offering at least theoretical applicability to remediation of the media of concern at the site. This list of options should be considered dynamic, flexible, and subject to revision based on further investigation findings, results of treatability studies, or technological developments.

Sections 5.1.1 and 5.1.2 present the primary and secondary screening of technologies. The technologies that survived this screening were considered to have potential applicability somewhere in Zone 5. Section 6.1.4 identifies technologies that are applicable to each plume.

5.2.1 Primary Technology Screening for Groundwater Remediation

During the primary technology screening process, specific technologies were identified for each GRA that might feasibly achieve the purpose of each action. This step identified potentially applicable technologies and eliminated technologies and process options considered to be incompatible with conditions of Zone 5 or the COCs, specifically CVOCs, benzene, CB, and arsenic. Figure 5.2 presents the primary technology screening. Process options retained from the primary screening were considered potentially applicable and were evaluated further during the secondary screening.

5.2.2 Secondary Technology Screening for Groundwater Remediation

Secondary technology screening was performed to reduce the number of technologies for further consideration. Technologies and process options carried forward from primary screening were compared and further evaluated on the basis of effectiveness, implementability, and relative cost.

5.2.2.1 No Further Action. The NCP requires that a No Further Action Alternative be evaluated as a baseline for comparison with other alternatives. The No Action Alternative represents a situation where no restrictions, controls, or active remedial measures are applied to the site. No action implies a scenario of "walking away from the site."

Under the No Action Alternative, no remedial action would be implemented to control the flux of contaminants moving toward the boundary of the base and the groundwater would not be remediated to reduce the concentration of contaminants in the aquifer. This alternative also presumes that DoD relinquishes control of the base to government or private entities without deed or groundwater-use restrictions and without the maintenance or enforcement of access controls.

The No Action Alternative requires that a site pose no unacceptable threat to human health and the environment. Current information indicates that remedial action is required.

5.2.2.2 Monitored Natural Attenuation. Monitored natural attenuation relies on the groundwater's natural ability to lower contaminant concentrations through physical, chemical, and biological processes until cleanup levels are met. Natural subsurface processes such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials may reduce contaminant concentrations to acceptable levels. Monitored natural attenuation is not the same as no action; the main difference is that the monitored natural attenuation option generally requires source control and performance monitoring to monitor its progress while no action does not (USEPA, 1997).

Consideration of this option usually requires modeling and evaluation of contaminant degradation rates and pathways and predicting contaminant concentration at down gradient receptor points, especially when the plume is still expanding/migrating. The primary objective of site modeling is to demonstrate that natural attenuation processes will reduce contaminant concentrations below regulatory standards or risk-based levels before potential exposure pathways are completed. In addition, long term monitoring must be conducted throughout the process to confirm that contamination concentrations are declining at rates consistent with meeting cleanup objectives within a reasonable time frame.

Target contaminants for monitored natural attenuation include fuel hydrocarbons, halogenated VOCs and SVOCs and some metals, when natural attenuation processes result in a change in the valence state of the metal that results in immobilization.

Until natural attenuation reduces contaminant concentrations to acceptable levels, institutional controls may be required, and the site may not be available for reuse until contaminant levels are reduced. Long term monitoring and associated cost are also required, and longer time frames may be required to achieve remediation objectives, compared to active remediation.

Implementability of monitored natural attenuation depends on the specific site conditions (such as geology, hydrogeology, and chemistry) but it is also influenced greatly by public acceptance.

The most significant costs associated with monitored natural attenuation are due to monitoring requirements, which include two major parts – site characterization and

performance monitoring. Site characterization determines the extent of contamination and contaminant degradation rates. Performance monitoring tracks contaminant migration, degradation rates, and cleanup status.

A natural attenuation modeling effort was conducted as part of this CMS to assess its effectiveness for use in the remediation of the shallow aquifer. Results of that effort indicate that natural attenuation can play a significant role in the remediation of the shallow aquifer in Zone 5 (see Section 3.2.3). Simultaneously with this CMS, Kelly AFB is engaged in development of a basewide fate and transport model that will evaluate natural attenuation processes to a greater level of detail than possible in this CMS. Results of that effort as they pertain to Zone 5 are included in Appendix G. Monitored Natural Attenuation will be retained for further evaluation.

5.2.2.3 Monitoring. Monitoring consists of collecting data to guide the remediation, evaluate the need for further action, and demonstrate that RAOs are being met. Monitoring for Zone 5 would be performed using well systems to measure groundwater levels and to collect samples for analysis of groundwater quality, including concentrations of VOCs.

Monitoring using well systems would be an effective method of determining regulatory compliance and evaluating the effectiveness of an interim remedial action for Zone 5 in meeting the RAOs. Monitoring would also be an effective way of showing trends in contaminant concentrations to demonstrate remediation by natural attenuation. The monitoring frequency and specific analyses would be modified as appropriate to obtain information specific to the selected purpose and interim remedial action. Monitoring alone would not be effective at preventing exposure to contaminants or limiting off base migration of contaminants, but would be an important element in identifying groundwater that presents an unacceptable risk and that requires control to prevent exposure.

Monitoring could be readily implemented. There are numerous wells on base and several wells off base that would provide a comprehensive monitoring network. Additional wells could be installed if needed using standard construction techniques. Because of state and public preferences, implementing monitoring alone without other measures to control contaminant migration might be difficult.

Because most or all of the needed wells are already installed and available, monitoring using well systems would involve a relatively low cost.

Because it is effective and readily implemented, monitoring using well systems will be retained for inclusion in remedial alternatives.

5.2.2.4 Institutional Controls. Institutional controls reduce or prevent public access to contamination. Although institutional controls alone do not contribute to remediation, they can reduce exposure to contaminants and thus reduce risk. They are frequently used in conjunction with other remedial elements, either during or at the completion of active remediation. Institutional controls consist of both physical barriers (e.g., fences) and administrative barriers (e.g., deed restrictions).

Institutional controls implemented by appropriate authorities at Kelly AFB could include rules, directives, policies, fencing, and warning signs. Such controls would be continued to ensure that on base access to Zone 5 is restricted during cleanup and to ensure appropriate

future use of the controlled land and underlying groundwater once remediation is completed. For privately owned land, administrative controls include laws, regulations, and ordinances adopted by state and local agencies to restrict the use of groundwater and to ensure appropriate future use. Kelly AFB has informed and will continue to inform state and local agencies of the condition of the shallow groundwater off base. These agencies have an established permitting process and are authorized to prohibit construction of private, community, or industrial wells that would withdraw groundwater from the shallow aquifer. The adoption of controls by state and local agencies for privately owned property is beyond the control and jurisdiction of Kelly AFB.

Existing institutional controls have been effective in preventing exposure to contaminated groundwater from Zone 5. It is expected that these controls would continue to be effective in the foreseeable future, with modification necessary as portions of East Kelly are released for non-DoD uses. Institutional controls are not an effective mechanism for limiting off base migration of contaminants.

Institutional controls are relatively easy to implement for Zone 5. They are believed to be effective because water is supplied to the surrounding community from the city water supply that derives from the Edwards Aquifer, resulting in little impetus to install shallow wells.

Institutional controls involve minimal cost.

Because they are effective in preventing exposure to groundwater with unacceptable risks, institutional controls will be retained for inclusion in remedial alternatives. Furthermore, because institutional controls are already in place, they will be incorporated as a baseline into all of the alternatives.

5.2.2.5 Containment.

Containment options retained for further evaluation include slurry walls, sheet pile walls, vertical extraction wells, collection trenches, horizontal extraction wells, and existing recovery systems. Existing recovery systems include: Recovery System SS042 (CS-2) North Bank (NB), SS002 (Industrial Waste Treatment Plant), and WP022 (E-3 IRP Zone 2); Recovery System SS003 (S-1); and Recovery System SS040 (OT-2 [MP]), ST006 (S-4), SS038 (S-8), and SS038 (S-8)/SS040 (OT-2 [MP]), Zone 3.

Slurry Walls. A slurry wall is a low permeability barrier used to contain contaminated groundwater, divert contaminated groundwater from a drinking water intake, divert uncontaminated groundwater flow around contamination, divert groundwater to a reactive barrier treatment system, or direct groundwater flow through one or more high permeability areas where it would be collected and treated ex situ. It is constructed by excavating a trench and backfilling with a bentonite-water slurry. The excavation is keyed into a lower confining layer. After excavation is complete, the slurry can be solidified either by adding a mixture of bentonite and soil or through the addition of cement to the original slurry. A variation of this technology is to install an impervious plastic membrane in a trench. In Zone 5, the slurry wall would extend down to the Navarro Group, which is the lower confining layer for the site.

A slurry wall would be effective in diverting groundwater flow around a contamination source, or diverting flow to a collection system or an in situ treatment system (such as a reactive barrier). If used to direct groundwater flow to a collection system or in situ treatment system, the effectiveness of the barrier would depend on the effectiveness of the associated system.

The implementability of a slurry wall depends on specific site characteristics such as depth to lower confining layer (typically should be less than 50 ft deep), buried utilities, building foundations and nature of the sediments.

Slurry walls are typically used where they can cost-effectively reduce the amount of groundwater to be collected or where they can reduce the length (and thus cost) of a reactive barrier (in situ permeable treatment wall). A slurry wall is not cost effective in situations where there is minimal groundwater flow and where that flow can be intercepted by a groundwater collection trench or wells. However, any cost advantage due to those factors would likely be outweighed by the high cost of installation at the required depths and location. Logistical interference such as buildings and underground utilities could make a slurry wall expensive.

Slurry walls are cost effective when collection system flow rates can be reduced significantly or where containment of the contaminated groundwater is the remedial objective. Because the saturated thickness is small and the permeabilities are low, the collection system flow rates are very low without the use of slurry walls. Because the capital costs of slurry walls are high (on the order of $150/lineal ft in Zone 5), they would not be cost effective.

Due to the difficulties in implementation and cost, slurry walls will not be retained for further evaluation.

Sheet Pile Walls. Sheet piling is another type of low permeability barrier used to divert groundwater in a manner similar to a slurry wall. It is constructed by driving adjacent, interlocking, steel sheets into the lower confining layer. Sheet pile walls are not initially water tight because of small gaps between the piles. However, with time the groundwater flow carries fines to the wall that tend to plug the gaps. Corrosion is generally not a concern for a sheet pile wall and the walls are considered permanent. Similar to a slurry wall, a sheet pile wall would be used to divert groundwater flow around the source of the contamination or to divert contaminated water flow to a reactive barrier.

As with a slurry wall, effectiveness would depend on diverting groundwater flow around the contamination source, or if used to direct groundwater, the effectiveness of the associated in situ reactive barrier.

Similar to slurry walls, implementability of sheet pile walls depends on specific site characteristics such as depth to lower confining layer, buried utilities, building foundations and nature of the sediments. Sheet piles are a proven technology, although driving piles through the large boulders could prove to be difficult. The sheet pile sections not fully penetrating to the Navarro Group would provide gates for contaminants to migrate from the source.

Like slurry walls, sheet pile walls are cost effective when collection system flow rates can be reduced significantly or where containment of the contaminated groundwater is the remedial objective. Because the saturated thickness is small and the permeabilities are low, the collection system flow rates are very low without the use of sheet pile walls.

The cost for a sheet pile wall would likely be less than that of a slurry wall. However, logistical interference such as buildings and underground utilities could make wall installation expensive.

Due to the difficulties of implementation, sheet pile walls will not be retained for further evaluation.

Vertical Extraction Wells. Extraction wells are used both to control the subsurface hydraulic gradient through withdrawal of groundwater and to collect groundwater (usually for subsequent treatment). They can thus be considered both a containment technology and part of a containment/discharge technology. When groundwater is removed, an artificial hydraulic gradient is established that controls or stops the flow of water past a point and indirectly prevents the migration of contaminants in the groundwater further downgradient from the wells. Typically, a well is screened through the aquifer to the depth where collection is desired. A submersible pump is placed in the bottom of the well, and the pump and well are sized to extract the appropriate flow rate. Vertical wells are installed by drilling directly down to the groundwater.

Vertical collection wells are generally an effective method for the removal of groundwater and are expected to be effective for controlling the migration of contaminants at Zone 5. However, the effectiveness of vertical wells in providing hydraulic control of the groundwater depends on proper design of the well system, which in turn, depends on proper characterization of subsurface conditions. Well productivity and the resulting groundwater capture zone created by pumping depend on the lithology present in the subsurface zone. The unconsolidated media lying above the Zone 5 Navarro Group are heterogeneous and anisotropic. Discontinuous layers of gravelly media, which would be the principal pathway for shallow groundwater flow and contaminant migration, are interspersed throughout the media. Defining geologic conditions to the extent required to confidently assure hydraulic containment with vertical wells could be difficult. However, this problem can be overcome to a large extent by spacing wells such that there is a substantial overlap in the predicted capture zones of individual wells.

A vertical well system could be readily implemented for the source contaminant plume at Zone 5. The use of well systems for hydraulic gradient control and groundwater recovery is a proven technology common in groundwater pollution control, and the installation of vertical wells would rely on standard construction techniques. Each well would have a separate pumping system that would require fairly routine operation and maintenance (O&M) to adjust well flow rates and pump depths (due to variations in thickness of the saturated zone).

Vertical wells would be a low to moderate cost compared to other methods of providing hydraulic control or recovering groundwater for treatment.

This technology will be retained for further evaluation in the remedial alternatives.

Collection Trenches. Collection trenches are used to collect groundwater, usually for treatment. This technology consists of a trench excavated to the lower confining layer and perpendicular to the groundwater flow, backfilled with a permeable material such as sand or gravel, containing a perforated pipe to collect groundwater. A sump with a submersible pump is located at one end (or multiple sumps depending on trench length) to collect groundwater, thus creating a continuous depression in the groundwater table along the trench alignment. Collection trenches generally require less maintenance than well systems because fewer pumps are involved, but are increasingly difficult to install as depth to groundwater increases.

Collection trenches are generally an effective method for intercepting groundwater plumes, especially where the groundwater flow is perpendicular to the axis of the trench. At Zone 5, they would be particularly effective because, unlike well systems, zones of differing permeability in the clayey gravel and the undulating surface of the Navarro clay would not result in lowered effectiveness for this technology.

In general, collection trenches can be implemented using readily available construction techniques, however, several conditions at Zone 5 could increase the complexity of implementation. First, logistical interference such as buildings and underground utilities could make trench installation expensive. Second, the presence of boulders in the clayey gravel might require the use of a large backhoe and shoring, versus less costly continuous trenching machines. Because trenching occurs within the aquifer, sheet piling may need to be installed to retard water during construction. Finally, because the depth to the Navarro Group is generally 30 to 40 ft or more, more sophisticated construction techniques may be required. Because collection trenches rely on natural groundwater flow, as compared to the induced gradient achieved with extraction wells, the rate of groundwater extraction tends to be lower for collector trenches than for extraction wells.

Because of the complexity of implementation, capital costs of a collection trench for the source contaminant plume site at Zone 5 would be relatively high.

Nonetheless, because of their high degree of effectiveness, trenches will be retained as a technology.

Horizontal Extraction Wells. Like vertical wells, horizontal wells are used for both hydraulic control and to collect groundwater, usually for treatment. Horizontal wells are installed using a directional drilling method to install perforated pipe several feet below the water table elevation. The method involves the use of a drill bit to advance the hole. The bit is specially fitted with a device for determining its depth and location during drilling. The screened pipe is pulled continuously behind the advancing drill bit. Drilling mud is commonly used to help facilitate the placement of the screened pipe. This technology is often used when there is some obstacle (e.g., surface structures, surface contamination) that prevents accessing groundwater through the use of vertical wells.

Although horizontal wells can be effective in some situations, they would not be very effective at the source contaminant plume at Zone 5. The undulating surface of the Navarro Group clay combined with a relatively thin saturated zone would make it difficult to place the horizontal collection pipe in the permeable clayey gravel. Portions of the pipe might inadvertently be completed in elevated zones of the Navarro clay, thus preventing

collection of groundwater from the overlying permeable layer. As with vertical wells, effectiveness would also suffer because of the heterogeneous nature of the media overlying the Navarro Group, and overlapping well capture zones would be required.

There are a few factors that may complicate the implementability of horizontal wells. Large boulders have been encountered in the clayey gravel and may make implementation of the horizontal drilling difficult. Furthermore because drilling muds are used, formation plugging can occur. Biodegradable drilling muds could be used instead but these could adversely affect the monitoring parameters by creating zones of enhanced biodegradation in the vicinity of the wells. This would have the effect of falsely indicating that the aquifer has been cleaned up when in fact contamination has biodegraded locally and the rest of the aquifer remains contaminated. The implementability of this technology at the site is poor, both because of the undulating surface of the Navarro Group as described above and because of concerns with the feasibility of construction and the addition of drilling muds.

Horizontal wells would be a low to moderate cost compared to other methods of providing hydraulic control and groundwater recovery. To withstand the forces introduced during installation, the well casing needs to be made of steel rather than less expensive plastic pipes.

Because of issues with effectiveness and implementability, horizontal extraction wells will not be retained for further evaluation in the remedial alternatives. Nevertheless, there may be some specific applications identified during remedial design that could benefit from the use of horizontal wells, and the technology may be reconsidered at that time.

Recovery System LF012 (D-2), IRP Zone 1. The groundwater recovery wells that make up the LF012 (D-2) Recovery System include 13 wells installed along the west bank of Leon Creek. The recovery wells are numbered sequentially from LF012RW034 to LF012RW046. The wells are constructed of 6-in. PVC and range in depth from 10.6 to 19.2 ft.

This recovery system is currently intercepting a portion of contaminated groundwater in Zone 1 and will continue to intercept a portion of the plume as long as the systems remain operational. Modeling efforts have indicated that this recovery system would eventually intercept Plume J (Appendix G).

Since the current recovery system will be effective for preventing the off base migration of plume J, the existing LF012 (D-2) recovery system will be retained for further evaluation.

Recovery Systems LF014 (D-4) and LF015 (D-5), IRP Zone 1. The groundwater recovery wells that make up the LF014 (D-4) Recovery System include 14 wells installed along the east bank of Leon Creek in Zone 1. The recovery wells are numbered sequentially from LF014RW032 through LF014RW045. The wells are constructed of 6-in. PVC and range in depth from 17.3 to 21.3 ft.

The groundwater recovery wells that make up the LF015 (D-5) Recovery System include 3 wells installed along the west bank of Leon Creek in the southern portion of Zone 1. The recovery wells are numbered sequentially from LF015RW008 to LF015RW010.

These recovery systems are currently intercepting a portion of contaminated groundwater plume located within Zone 1 and will continue to intercept a portion of the plume as long

as the systems remain operational. Modeling efforts have indicated that this recovery system would eventually intercept Plume H (Appendix G).

Since the current recovery system will be effective for preventing the off base migration of plume H, the existing LF014 (D-4) and LF015 (D-5) recovery systems will be retained for further evaluation.

Recovery System SS042 (CS-2) IRP Zone 2. There are 10 groundwater recovery wells and a 200 ft long collection trench that make up the SS042 (CS-2) Recovery System. The wells are located along the southwest bank of Leon Creek. The recovery wells are numbered sequentially from SS042RW071 to SS042RW080. The CS2R11 standpipe allows for collection of the groundwater recovered by the trench. The wells are constructed of 6-in. PVC and range in depth from 13.1 to 23.6 ft.

This recovery system is currently intercepting a portion of the Zone 2 groundwater plume and will continue to intercept a portion of the plume as long as the systems remain operational. Modeling efforts have indicated that this recovery system would eventually intercept Plume D, the western portion of Plume F, and a portion of Plume I (Appendix G).

Since the current recovery system will be effective for preventing the off base migration of plume D and portions of Plumes F and I, the existing SS042 (CS-2) recovery system will be retained for further evaluation.

Recovery System SS042 (CS-2) North Bank, SS002 (Industrial Waste Treatment Plant), and WP022 (E-3 IRP Zone 2). The groundwater recovery wells that make up the SS042 (CS-2) NB Recovery System include 13 wells installed just east of SS002 (the former industrial waste treatment plan [IWTP]), north of Leon Creek in Zone 2. The recovery wells are numbered sequentially from SS042RW081 to SS042RW093. The wells are constructed of 6-in. polyvinyl chloride (PVC) and range in depth from 27.6 to 39.8 ft. The screened interval generally varies from 10 to 15 ft, depending on the well.

The groundwater recovery wells that make up the ITWP Recovery System include 7 wells installed just south of SS002 (IWTP), north of Leon Creek in Zone 2. The recovery wells are numbered sequentially from SS002RW007 to SS002R013. The wells are constructed of 6-in. PVC and range in depth from 21.6 to 30.0 ft. The screened interval generally varies from 10 to 20 ft depending on the well.

The groundwater recovery wells that make up the WP022 (E-3) Recovery System include nine wells installed around the WP022 (E-3) Source Area (former evaporation pit and landfill) north of Leon Creek in Zone 2. The recovery wells are numbered sequentially from WP022RW017 to WP022RW025. The wells are constructed of 6-in. PVC and range in depth from 15.5 to 25.8 ft. The screened interval generally varies from 10 to 15 ft depending on the well.

Groundwater in the area flows in the alluvial clayey gravel overlaying the Navarro clay. Groundwater under the SS042 (CS-2) site (near the SS042 [CS-2] NB collection system) was found from 4 to 14 ft below the ground level in a saturated thickness ranging from 12.4 to 2.0 ft. Groundwater under SS002 (near the IWTP and WP022 [E-3] collection systems) was found from 11.4 to 21.6 ft below the ground level in a saturated thickness ranging from 12.7

to 4.8 ft. The potentiometric surface map for the site indicates groundwater flow direction to the southwest toward Leon Creek. However, there appears to be a channel-like feature or "low" in the Navarro clay that causes groundwater flow from site WP022 (E-3) in an southeasterly direction through the former IWTP site and site CS02.

These recovery systems are currently intercepting a portion of the PCE and TCE contaminant plume located within Zones 2, 3, and southern portion of Zone 5 and will continue to intercept a portion of the plume as long as the systems remain operational. These recovery systems do not have the capacity or zone of hydraulic influence to prevent the continued migration of the PCE/TCE plume from the southern portion of Zone 5 into Zone 2 and eventually into Leon Creek. Modeling efforts have indicated that these recovery systems currently intercept approximately 70 percent of the ambient groundwater flow in excess of 5 µg/L of TCE (CH2M HILL, 1997d).

Expansion of these recovery systems would involve the installation of vertical wells and/or collection trenches. Vertical wells would be a low to moderate cost compared to other methods (more costly trench installation) for recovering groundwater for treatment. Continued operation of the recovery systems would have low to moderate costs, depending on the extensiveness of any system expansion and additional hardware installation, if any.

Since the current recovery systems are useful for the recovery of the groundwater that penetrates their zone of influence, the use of the existing SS042 (CS-2) NB, ITWP and WP022 (E-3) recovery systems will be retained for further evaluation.

Recovery System SS003 (S-1). The groundwater recovery wells that make up the SS003 (S-1) Recovery System include 6 wells installed along the north and east of site SS003 (S-1) in the northeastern portion of Zone 5. The recovery wells are numbered sequentially from SS003RW111 to SS003RW116. The wells are constructed of 6-in. PVC and range in depth from 31.8 to 43.1 ft. The screened interval generally varies from 10 to 19.8 ft depending on the well. These wells penetrate 5.5 ft into the underlying Navarro clay. Groundwater is pumped to the surface and subsequently to an oil/water separator and air stripper via a 2-in. HDPE collection pipe.

Groundwater in the area flows in the alluvial clayey gravel overlaying the Navarro clay. Groundwater under the SS003 (S-1) site was found from 20 to 35 ft below the ground level in a saturated thickness ranging from 24 to 8 ft. The potentiometric surface map for the site indicates groundwater flow direction to the east. However, there appears to be a channel-like feature or "low" in the Navarro clay that causes groundwater flow from site SS003 (S-1) in an northeasterly direction toward the nearby base boundary.

This recovery system is currently intercepting a portion of the SS003 (S-1) source contaminant plume located in the northern portion of Zone 5 (Plume C) and will continue to intercept a portion of that plume as long as the system remains operational. Modeling efforts have indicated that this recovery system currently intercepts only a portion of the upgradient groundwater flow through the SS003 (S-1) source and is not affecting downgradient flow (CH2M HILL, 1997d). This may be in part due to the extremely low groundwater extraction rates observed at this system (1 gallon per minute [gpm]).

The interim action implemented for the site SS003 (S-1) sump area and smear zone is excavation of the contaminated soil to the top of the Navarro Group in the sump area and

dual phase extraction of groundwater and vapor in the smear zone (CH2M HILL, 1998c). The dual phase system included 10 new groundwater extraction wells throughout the groundwater contaminant plume. This system is remediating both soil and groundwater.

The recovery system is also being used for the recovery of the groundwater to assist in depressing the water table as much as possible to allow oxygen to be supplied to the contaminated soils in the zone of water table fluctuations.

Recovery System SS040 (OT-2 [MP]), ST006 (S-4), ST008 (S-6), SS038 (S-8), and SS038 (S-8)/ SS040 (OT-2 [MP]), Zone 3. Modeling efforts have indicated that these recovery systems will not influence any contaminant plume originating from Zone 5.

Since the Zone 3 system would not intercept any Zone 5 contaminant plumes, this system will not be retained for further evaluation.

5.2.2.6 In Situ Treatment. There were five in situ treatment options that were retained for further evaluation. These include air sparging, enhanced biological degradation, permeable treatment walls, iron colloids, and chemical oxidation.

Air Sparging. Air sparging involves injecting air into the aquifer via a well or horizontal pipe. Air travels horizontally and vertically through both the soil and groundwater columns, creating an underground stripper that removes contaminants by volatilization. These air bubbles carry the contaminants to a vapor extraction system. SVE is usually implemented in conjunction with air sparging to remove the generated vapor phase contamination from the unsaturated zone. Subsequent to vapor extraction, the VOCs are treated as necessary to meet emission standards, then discharged. Typically, this technology is designed to operate at high flow rates to maintain increased contact between groundwater and soil and strip more groundwater by sparging. The technology has the advantage of stripping contaminants from the groundwater and from the soil vadose zone. The introduction of air at lower flow rates can promote biodegradation. Fracturing of the plume is a concern with this technology and the potential exists for vapor intrusion into nearby building basements due to increased pressure in the vadose zone.

The effectiveness of this technology is highly dependent upon soil and aquifer permeability, presence of low permeability layers, groundwater flow rate, contamination depth and concentration. Although in situ air sparging is likely to be at least somewhat effective for groundwater at the site, there is insufficient information to evaluate the overall effectiveness and rate of degradation. Pilot-scale treatability tests would be required to determine whether the effectiveness warrants further consideration (USACE, 1997). Air sparging systems typically have a zone of influence of 20 to 25 ft (USACE, 1997). The zone of influence should be much less in many of the plumes having saturated thicknesses of less than 10 ft.

Recirculating well technology was also considered but was screened out due to limited effectiveness because 1) aquifer heterogeneities (poor circulation cell geometry), 2) poor cost effectiveness in the majority of the plumes due to close well spacing requirements (which results from the thin saturated thickness and causes a very narrow circulation cell), 3) introduction of air into the well could cause continual maintenance problems associated

with well screen fouling (because of inorganic precipitates and bacterial growth). Other injection systems (such as dual-phase, horizontal two-pipe systems) are not considered feasible because of the difficulty of reinjecting water into the low permeability subsurface.

The capital cost for air sparging is relatively moderate when compared to other insitu treatment technologies. However, the annual operation cost is higher because of the need to treat extracted vapors (U.S. EPA, 1994).

Air sparging is effective in the removal of VOCs and is easily implemented. However, consideration must be given to the problem of unknown soil and aquifer permeability and the operation costs associated with off-gas treatment (U.S. EPA, 1994).

Based on its potential as an effective technology, air stripping will be retained for further evaluation of the remedial alternatives.

Enhanced Biological Degradation. In situ biological degradation relies on microbial processes to destroy contaminants or convert them to less toxic forms. Biological agents are generally classified as either aerobic or anaerobic.

Biodegradation of organic chemicals generally depends on the availability of organic materials to serve as electron donors and thus an energy source for the microbe. Higher carbon oxidation states correspond to lower energy yields and thus provide less energetic incentive for an organism to degrade it. The more chlorine atoms present, the higher the oxidation state. For chlorinated ethene, the oxidation states follow the order PCE>TCE>DCE>VC.

Microbial degradation of organic compounds involves two main processes: direct utilization of the organic chemical as an energy source (primary substrate); or destruction of the organic chemical via non-specific enzymes produced by the microbes (co-metabolism). In the latter case, another energy source (secondary substrate) must be available for the microbes. Co-metabolism has been cited as the most promising in situ biological degradation approach for CVOCs (McCarty and Semprini, 1994).

Of the organic COCs at Zone 5, benzene and CB can serve as primary substrates and degradation can be either aerobic or anaerobic but generally proceeds most rapidly aerobically (Bossert and Compeau, 1995).

Highly chlorinated solvents such as PCE and TCE can serve as the primary substrates and undergo reductive dechlorination involving anaerobic microbes (Adriaens and Vogel, 1995). The reduction of PCE and TCE by this mechanism generally leads to the production of VC, which is of greater concern from a toxicological standpoint than either PCE or TCE. One solution to this problem is to create an aerobic zone downgradient from the anaerobic zone and degrade the VC aerobically.

Aerobic methanotrophic organisms have been used to degrade chlorinated solvents co-metabolically. In general, methanotrophs can be stimulated by the injection of oxygen and methane into the groundwater. Methane inhibits the biotransformation of TCE, trans-DCE and VC. Alternative electron donors, such as formate or methanol, alleviate this problem (Adriaens and Vogel, 1995).

PCE is not co-metabolically oxidized, probably because of a steric effect (the enzyme is physically prevented from reacting with the PCE molecule because of the way the chlorine atoms are arranged around the carbon atoms) (Wackett, 1996). A sequential anaerobic/aerobic transformation may be used in situations where PCE is present (Vogel, 1994). First, the PCE is anaerobically reduced to TCE and DCE. These products are then aerobically co-metabolized.

Microbes may either be indigenous or imported, although most sites have the necessary bacteria so that enhancement of the environment to promote growth of the bacteria is all that is needed.

Enhancement of the microbial environment involves adjusting chemical conditions (such as the amount of free oxygen and pH), supplying the proper nutrients (such as nitrates), and possibly supplying an energy source (for co-metabolism). Chemicals necessary for microbial stimulation can be added to the aquifer through conventional injection wells. Nutrients (such as nitrates, ammonia or urea), substrates (such as methanol), oxidants (such as air or hydrogen peroxide) and electron donors (methanol or hydrogen) can be added to the groundwater. Recent field tests indicate that nutrients are seldom limiting and nutrient addition may not be necessary in many cases (Dupont, 1992).

A novel method for introducing hydrogen to stimulate anaerobic dechlorination is through the use of Hydrogen Release Compound (HRC), a patented, proprietary food-grade polymer that degrades to lactic acid. The lactic acid in turn degrades to acetic acid producing hydrogen. HRC may be applied using retrievable filter socks placed in completed monitoring wells, or in a water and HRC powder slurry mixture. The cost of using HRC may be low compared to traditional technologies, such as injecting a methanol solution into the aquifer. No field demonstrations of this technology have been performed, however, Regenesis, the owner of the patent, has proposed a field demonstration through the Air Force Center for Environmental Excellence (AFCEE).

Oxygen Release Compound (ORC) can be used to enhance oxygen levels in the groundwater. ORC is a patented formulation of magnesium peroxide, MgO_2, which, when moist, releases oxygen slowly. The hydrated product is magnesium hydroxide, $Mg(OH)_2$. ORC is useful as a slow release source of oxygen. ORC has been used in the successful remediation of dissolved phase TPH and BTEX compounds. ORC is most frequently used to address dissolved phase contamination plus sorbed material in the saturated, capillary fringe and smear zones. ORC should not be used when more than a sheen of free product is evident.

For groundwater treatment, a typical in situ biological treatment system might consist of an upgradient well for injecting air and/or nutrients and to allow for pH adjustment (if necessary). A downgradient extraction well might also be provided to hydraulically control the zone of in situ degradation. The extracted water might be treated, if necessary, before augmentation with the methane source and nutrients prior to reinjection in the upgradient well.

In situ biodegradation is effective for a variety of organic compounds, including chlorinated compounds. Rates of degradation are highly dependent on the in situ conditions, but these can be adjusted for optimum conditions.

The implementability of in situ biological treatment is complicated by heterogeneous conditions in an aquifer, which occur in Zone 5. While a system of extraction and injection wells could provide good hydraulic control, the primary substrate or nutrients would tend to distribute along the most permeable zones of the aquifer. The effects of this phenomenon could be minimized by limiting the remediation to a small area such as the most contaminated portion of the plume, and injecting nutrients at a low enough rate as to allow them to permeate the aquifer. Dispersion and diffusion would then spread the additives throughout the contaminated portion of the aquifer.

Operating costs for in situ biodegradation would be low to moderate because of the need to inject solutions into the groundwater.

Based on their potential as effective technologies, enhanced biological degradation options will be retained for further evaluation in the remedial alternatives.

Permeable Treatment Walls. A permeable treatment wall (also referred to as a reactive barrier) consists of a trench excavated perpendicular to the groundwater flow to the depth of groundwater contamination. The excavation is then backfilled with a treatment medium. The treatment medium could consist of either granular activated carbon (GAC) or granular iron. One of the major concerns for the use of permeable treatment walls is the useful life of the treatment bed. As with slurry walls, implementability of a permeable treatment wall depends on specific site characteristics, such as depth to lower confining layer (typically should be less than 50 ft deep), buried utilities, building foundations and nature of the sediments.

While a GAC treatment wall would be effective in capturing all of the COCs, except arsenic, its effectiveness would be reduced by the adsorption of naturally occurring dissolved organics. A GAC treatment wall would not be cost-effective since it would require routine replacement.

Due to the reduced effectiveness, difficulty of implementation, and costs associated with replacement, a GAC permeable treatment wall will not be considered further for the source contaminant plume at Zone 5.

Zero-valent metal reduction uses granular iron to produce strongly reducing conditions in the groundwater within and immediately downgradient of the wall. The reducing conditions in turn cause the CVOCs, such as PCE and TCE, to reductively dehalogenate to harmless by-products like ethane. The iron is added as grindings, either in a relatively narrow (12- to 18-in. wide) continuous wall, or in thicker and shorter permeable "gates." The strongly reducing conditions may also cause mobilization of naturally occurring inorganic constituents such as manganese, although the limited field data available do not indicate that this has been a problem.

Theoretically, the useful life is controlled by the amount of fouling of the media by inorganic precipitates, largely calcium and magnesium. The latest data shows about the life of this reactive media to be between seven and 10 years and possibly longer.

Precipitates form in the interstices between the iron filings as a result of a pH increase above 9.5. The pH increases because the heavily reducing conditions cause hydrolysis of water, thus liberating hydrogen gas and hydroxide ions. Fouling could be a significant problem at the site because the groundwater has a high natural hardness. The effectiveness

of a zero-valent iron wall varies with the contaminant. The mechanism of reductive dehalogenation by zero-valent iron is not currently well understood. Experimental evidence suggests that dechlorination is more rapid at saturated carbon centers (e.g., carbon tetrachloride and hexachloroethane) than unsaturated carbon centers (e.g., TCE and PCE) (Johnson et al., 1996). With the wall, the reduction is straight to ethene/ethane rather than the sequential daughter product reduction (such as vinyl chloride). An advantage of this technology is the potential for low O&M costs. This is a passive technology, which does not require an active pump and treat system. However, the low O&M cost is offset by relatively high capital and replacement costs. Logistical interference such as buildings and underground utilities could make wall installation expensive. The useful life is relatively long (seven to ten years) therefore, the cost of bed replacement will not greatly affect the present worth cost of this technology.

Based on its potential as an effective technology, the zero-valent iron barrier for the COCs will be retained for further evaluation on the remedial alternatives.

Iron Colloids. A variation on the zero-valent iron barrier technology discussed above is the injection of micrometer-sized zero-valent (Fe^0) colloids into the aquifer to form a chemical treatment zone, which would act to chemically reduce the CVOC contaminants. Emplacement of the colloids in an effective configuration can be controlled by a combination of vertical injection and withdrawal wells, or through the use of a single horizontal well. The micron-sized Fe^0 colloids selectively remove targeted groundwater contaminants while permitting water and other nontargeted constituents to pass through freely (Kaplan et al., 1994). Laboratory and field studies have shown that the Fe^0 destroys chlorinated solvents (e.g., carbon tetrachloride, PCE, and TCE) and immobilizes several hazardous metals such as chromium, selenium, technetium, and uranium.

This technology has been limited to field demonstrations to date. There is little information upon which to judge its effectiveness and cost. For this reason, this technology will not be considered further.

Chemical Oxidation. In situ chemical oxidation, via injection of aqueous solutions into the groundwater, has very limited application in groundwater remediation. In situ chemical oxidation is generally limited to remediation of metal contamination. One of the difficulties is that oxidation is non specific and while the target species may be immobilized, other metals may be mobilized.

Of the COCs in Zone 5, arsenic would be target for in situ chemical oxidation. Under reducing conditions, arsenic contamination in groundwater is typically As (III) existing as arsenite (AsO_3^{3-}) and the protonated forms H_3AsO_3, $H_2AsO_3^-$, and $HAsO_3^{2-}$. Under oxidizing conditions, As(V) is the predominant form and can exist as arsenate (AsO_4^{3-}) and the protonated forms H_3AsO_4, $H_2AsO_4^-$, and $HAsO_4^{2-}$. Arsenate and the other protonated forms generally behave as chelates and can precipitate when metal cations, such as iron or manganese, are present (Bodek et al., 1988). This precipitation mechanism is the basis for in situ treatment of arsenic contaminated groundwater. Increasing the oxygen content of the groundwater can oxidize the As (III) to As (V) which can then be precipitated as a metal complex such as $FeAsO_4$ or $Mn_3(AsO_4)_2$ or co-precipitated with Mn- or Fe-hydroxides from the naturally occurring manganese and iron. Injection of potassium permanganate ($KMnO_4$) has been used to effect the oxidation of As(III) (Matthess, 1981).

There is very little information concerning the effectiveness and implementability of in situ chemical oxidation, and for this reason, it will not be considered further.

5.2.2.7 Ex Situ Treatment

There were nine ex situ treatment options retained for further evaluation. These options include the use of new and existing treatment systems. New treatment systems include UV oxidation, ion exchange, precipitation, air stripping, adsorption, and bioreactors. Existing treatment processes include the EPCF, San Antonio Publicly-Owned Treatment Works (POTW) , the Zone 2 GWTP, and the SS003 (S-1) treatment system, and the Zone 3 GWTP.

Ultraviolet Oxidation. Ultraviolet oxidation is a destruction process that oxidizes the organic constituents in water by the addition of strong oxidizers and irradiation with ultraviolet (UV) light. The oxidation reactions are achieved through UV light activation of ozone and/or H_2O_2 to produce hydroxyl radicals. The hydroxyl radicals are very strong oxidizers that react with and destroy most organic compounds. Experimental evidence suggests that UV oxidation does not create toxic side products, but that it can produce di- and trichloroacetic acids in small concentrations (Hirvonen et al., 1996). Di- and trichloroacetic acids have toxic effects similar to acetic acid (LD_{50} for rats orally is about the same order of magnitude for all 3 compounds) (Budavari, 1989). If complete mineralization occurs, the final products are carbon dioxide, water, and salts. An advantage of UV oxidation over other technologies, such as air stripping, is the oxidation process destroys the contaminants, while air stripping transfers the contaminants to another medium (air) which requires a treatment system to control emissions.

Ultraviolet oxidation is very effective on a variety of industrial solvent-related organics. UV oxidation is an especially effective treatment for organics at low concentrations (less than 100 mg/L) and against organics having unsaturated carbon centers such as olefins (i.e., PCE, TCE, etc.) and aromatics (i.e., benzene and CB) (Topudurti et al., 1993). Ultraviolet oxidation is not an effective treatment for arsenic, and a UV oxidation system would require an arsenic removal pretreatment step if arsenic is present in the water to be treated.

Ultraviolet oxidation could be readily implemented. It is a proven technology and a variety of vendors have systems available for a range of flow rates.

A UV oxidation system would be subject to many of the same concerns regarding fouling from naturally occurring minerals as would air stripping. A pretreatment process may be needed to control fouling.

Ultraviolet oxidation tends to have relatively high capital costs, and high electrical usage of UV oxidation leads to increased O&M costs. Typical operating costs of UV oxidation systems range between $0.33/1,000 gallons and $1.10/1,000 gallons. However, UV oxidation is typically cost-effective for use on contaminants that are difficult or expensive to treat with other treatment technologies.

Ultraviolet oxidation will be retained for further evaluation because it is an effective and easily implemented technology for the source plume COCs at Zone 5.

Ion Exchange. Ion exchange removes ions from the aqueous phase by the exchange of cations or anions between the contaminants and the exchange medium. Ion exchange materials may consist of resins made from synthetic organic materials that contain ionic functional groups to which exchangeable ions are attached. They also may be inorganic and natural polymeric materials. After the resin capacity has been exhausted, resins can be regenerated for re-use.

Ion exchange can remove dissolved metals from aqueous solutions. Other compounds that have been treated include nitrate, ammonia nitrogen, and silicate.

Factors that may affect the applicability and effectiveness of this process include: oil and grease in the groundwater which may clog the exchange resin; suspended solids content greater than 10 ppm, which may cause resin blinding; the dissolved solids content, if greater than 500 ppm; sulfate levels greater than 25 ppm; the pH of the influent water, which may affect the ion exchange resin selection; and oxidants in groundwater may damage the ion exchange resin. Also, the valence state of the contaminant could affect the applicability and effectiveness of this process.

Wastewater is generated during the regeneration step and will require additional treatment and disposal. Alternatively, spent ion exchange resin could be disposed without regeneration.

For this CMS, the COC that ion exchange would be removing is arsenic. Because the Zone 5 groundwater is under reducing conditions, arsenic exists in the As (III), or arsenite, valence state. Ion exchange performs most effectively in the As (V), or arsenate state. It has been demonstrated that ion exchange is 80 times more effective in the As (V) valence state. Therefore, As (III) must be oxidized to As (V) to obtain effective results (Clifford, 1990).

With pretreatment, ion exchange is implementable for this effort. A stage would be required to oxidize the arsenic, potentially adjust the pH, and possibly remove any excess suspended or dissolved particles (see the following section). Because ion exchange is a proven technology, these pretreatment stages are easily implemented.

Key cost factors include pretreatment requirements, discharge requirements and resin utilization, and regenerant use and efficiency. The cost is better than most groundwater treatment technologies.

Ion exchange will be retained for further evaluation because it is effective, easily implemented, and cost-effective for the removal of metals and arsenic.

Precipitation. Precipitation of metals has long been the primary method of treating metal-laden industrial wastewaters. As a result of the success of metals precipitation in such applications, the technology is being considered and selected for use in remediating groundwater containing heavy metals and arsenic. In groundwater treatment applications, the metal precipitation process is often used as a pretreatment for other treatment technologies (such as chemical oxidation or air stripping) where the presence of metals, especially calcium, magnesium, and iron, would interfere with the other treatment processes.

This process transforms dissolved contaminant into an insoluble solid, facilitating the contaminant's subsequent removal from the liquid phase by sedimentation or filtration. The process usually uses pH adjustment, addition of a chemical precipitant, and flocculation. Typically, metals precipitate from the solution as hydroxides, sulfides, or carbonates. The solubilities of the specific metal contaminants and the required cleanup standards will dictate the process used.

Arsenic exists as either arsenite or arsenate forms in water. Ex situ treatment typically involves coprecipitation by the addition of a polyvalent metallic coagulant (such as iron) to produce a hydroxide floc. A typical treatment system involves the addition of ferrous or ferric iron at a pH of between 5 and 6 followed by a pH adjustment to 8 or 9 by adding lime (Nyer, 1992). Precipitated arsenic-bearing solids are then separated from the water using conventional solid/liquid separation techniques (e.g., clarification, flocculation, and/or filtration). The process may generate a toxic sludge requiring proper disposal. The hydroxide sludge must pass TCLP or be treated prior to land disposal.

Precipitation of arsenic is an effective treatment method for arsenic removal down to currently established discharge limits. Precipitation is readily implementable as a pretreatment step prior to removal of organics. A precipitation step would probably be needed in any case to reduce the levels of calcium, magnesium, and iron in the water prior to organic removal. Costs for treatment are moderate, but could require more expensive treatment if discharge standards are made more stringent.

Because of its effectiveness in treating groundwater with metals and/or arsenic contamination, precipitation will be retained for further evaluation.

Air Stripping. Air stripping is a technology in which VOCs are transferred from the groundwater to the air stream. The VOCs are treated as necessary to meet emission standards, then discharged. In general, the more interfacial surface area between the water and air phase, the more effective the technology. Packed towers and aeration tanks are two methods of maximizing the interfacial surface area. A typical packed tower air stripper includes a spray nozzle in the top of the tower to distribute contaminated water over the packing in the column, a blower to force air upward through the tower, and a sump in the bottom of the tower to collect the decontaminated water. Aeration tanks strip volatile compounds by bubbling air into a tank through which contaminated water flows. An air blower and a distribution manifold are designed to ensure air-water contact without the need for any packing materials.

Air stripping is an effective technology for treatment of many VOCs. Removal efficiencies of 80 to 99 percent are common using air stripping. Carbon adsorption is generally effective

for removing VOCs from the air stripping off-gas. However, preliminary calculations (Appendix J) indicate that air stripper off-gas treatment would not be required for Zone 5 COCs to meet air emission standards. Air stripping is not an effective treatment for arsenic and an arsenic removal step would be required prior to air stripping.

From a technical standpoint, air stripping is a proven and commonly used technology that is relatively simple to implement. However, regular maintenance is required to remove mineral precipitates and biological growth from the air stripper packing and for proper operation of the pumps and blowers. There is a limited amount of analytical data regarding hardness and iron content in the Zone 5 aquifer and the resulting mineral precipitation. Analytical results from wells located in Zone 5 indicate that iron concentrations are in the 200 to 3,000 ppb range and hardness is in the range from 300 to 400 ppm (as calcium carbonate). Iron concentrations are not particularly high but would probably require periodic maintenance to remove iron buildup unless steps were taken to remove the iron (Nyer, 1992). However, the hardness is of concern, and some type of pretreatment, such as pH adjustment, may be needed to prevent mineral fouling of the packing in the air stripping tower. Fouling of an aeration tank is much less of a problem than a packed tower. The SS003 (S-1) air stripper uses a shallow tray design and an iron prefilter to alleviate the problem of fouling.

From a non-technical standpoint, air stripping without off-gas treatment can be more difficult to implement. Rather than immobilizing or destroying contaminants, air stripping alone transfers the contaminants from one medium to another (in this case from water to air). The EPA has a clear preference for technologies that immobilize or destroy contaminants as opposed to those that simply transfer contaminants from one medium to another. In addition, the community has previously expressed concern over VOC emissions from Kelly AFB in general and there likely would be some concern regarding air stripping without some form of off-gas treatment.

The capital and operating costs for air stripping are relatively low when compared to other ex situ treatment technologies such as UV oxidation. Operating costs increase substantially if off-gas treatment is required. Operating costs for air strippers without off-gas treatment are typically in the $0.04/1,000 gallons to $0.17/1,000 gallons range. With off-gas treatment, operating costs can increase by as much as $1 to $2 per 1,000 gallons treated (Nyer, 1992).

If air emission controls are implemented for air stripping, UV oxidation would be more cost competitive. UV oxidation was selected as a representative process option for the purpose of estimating treatment system costs, but air stripping will be re-considered during pre-design.

The SS003 (S-1) air stripper , which does not incorporate off-gas treatment, will be retained because it is an effective remediation system and the remaining duration of operation is limited (a few years) from the time the SS003 (S-1) soil remediation is implemented.

Adsorption. Liquid phase GAC adsorption is a full-scale technology that has been used for many years in the treatment of municipal, industrial, and hazardous wastes. In this application, groundwater is pumped through beds of activated carbon to which organic contaminants are adsorbed. Removal efficiencies for organic chemicals depend largely on the solubility of the contaminants and the surface area of the carbon. The pH, ionic strength,

and competition between contaminants for adsorption sites can influence the effectiveness of the removal, but removal of concentrations below detection limits is feasible for many organic contaminants. Activated carbon units have moderate maintenance demands, and their performance needs frequent monitoring. The adsorbed contaminants would be destroyed during carbon regeneration offsite.

Carbon adsorption is an effective ex situ treatment for removal SVOCs, but is less effective for removal of CVOCs (Nyer, 1992) and arsenic. The GAC would also adsorb naturally occurring organic chemicals that are not harmful and do not require treatment, thus increasing the carbon replacement cost.

The use of carbon adsorption results in greater operating expense relative to other technologies available for VOC removal, such as air stripping.

Because of the limited effectiveness and relative costs, liquid phase GAC absorption will not be retained for further consideration.

Bioreactors. Bioreactors degrade contaminants in water with microorganisms through attached or suspended biological systems. In suspended growth systems, such as activated sludge, fluidized beds, or sequencing batch reactors, contaminated groundwater is circulated in an aeration basin where a microbial population aerobically degrades organic matter and produces carbon dioxide, water, and new cells. The cells form a sludge, which is settled out in a clarifier and is either recycled to the aeration basin or disposed of. In attached growth systems, such as upflow fixed film bioreactors, rotating biological contactors, or trickling filters, microorganisms are established on an inert support matrix to aerobically degrade water contaminants. Bioreactors are used primarily for SVOCs, fuel hydrocarbons, and any biodegradable organic material. VOCs are generally more resistant to biodegradation.

The effectiveness of biodegradation is dependent on specific site conditions such as chemical and physical properties of the water and microbial interactions. Biodegradation targets specific organic compounds, unlike typical industrial or municipal wastewater treatment systems that reduce the total organic compounds present. The interaction of the various factors that affect the effectiveness of a biodegradation system are generally complex enough that a treatability study is needed for proper design. Treatability studies typically study site-specific differences in such factors as water and soil chemistry, species of microbes, mode of microbial metabolism, and influence of inhibiting or enhancing chemicals.

Bioreactors require sufficient organic substrate to maintain biological growth. The relatively low concentrations of organic contaminants in the groundwater would be too low to promote sufficient growth in a bioreactor. Consequently, addition of an organic substrate would be needed, increasing the operating cost of the system.

Although biodegradation is likely to be at least somewhat effective for the COCs in the groundwater at Zone 5, there is insufficient information to evaluate the overall effectiveness and rate of degradation. Both laboratory-scale and pilot-scale treatability tests would be required to determine whether the effectiveness warrants further consideration.

Ex situ biological treatment would be relatively easy to implement, once the proper conditions for microbial activity are determined, because bioreactors could be used to provide temperature control and good dispersal of nutrients.

Moderate capital and operating costs would be expected. The overall cost for this technology would be increased by the need for treatability studies.

Because of the absence of information to determine effectiveness and an optimized treatment system, ex situ biological degradation will not be retained for further evaluation.

San Antonio POTW. Treatment at the San Antonio Water System (SAWS) Dos Rios POTW would involve constructing discharge piping to the San Antonio sanitary sewer system. The San Antonio POTW includes the following treatment processes: primary clarification, activated sludge, secondary clarification, chlorination, and dechlorination. The POTW currently treats an average of 72 mgd of wastewater and has the capacity to treat 96 mgd. VOC removal efficiencies of about 90 percent or more are expected to be easily achieved. Based on discussions with SAWS, there are concerns about the ability of SAWS to treat the effluent from Zone 5. For costing purposes, it has been assumed that SAWS will not be able to accept Zone 5 groundwater for treatment. However, if it is determined at a later date that SAWS could treat the Zone 5 groundwater, this option can be reevaluated during the design phase.

Although the extracted groundwater would probably meet specific numerical standards for treatment, there is a concern that there could be violations of the general discharge prohibitions for the following reasons:

- The contaminants may cause inhibition or toxicity effects that may adversely impact the SAWS treatment processes.
- Contaminants may adversely affect SAWS sludge digestion and composting operations. The compost may ultimately collect some of the contaminants and SAWS is committed to developing a high-quality compost for community use.
- If there are any unforeseen treatment problems, these may have potential impacts to the operating permit of the treatment facilities.

In addition to the concerns regarding treatment by SAWS are concerns regarding the collection system. The main collection system in the immediate area is about 3,600 ft of 12-in. concrete pipe. The pipe is heavily deteriorated and has perimeter cracks throughout the pipe. The following are concerns regarding the collection system:

- The introduction of contaminants may contribute or accelerate the degradation of the pipe material and structural integrity, and could contribute to the deterioration of rubber gaskets that connect pipe joints.
- Occasional backups and stoppages occur in the collection system and if the groundwater contaminants are present when the backups and stoppages occur, customers homes could be contaminated.

Because of the reasons cited above, treatment of extracted groundwater in SAWS facilities will not be retained for further evaluation.

"The GWTP currently processes extracted groundwater from the LF012 (D-2), LF014 (D-4), and LFO15 (D-5), WP021 (E-1), WP022 (E-3), SS002 (IWTP), SS042 (CS-2) and SS042 (CS-2) NB, SS040 (OT-2 [MP]), ST006 (S-4), ST008 (S-6), SS038 (S-8) and SS038 (S-8)/ SS040 (OT-2 {MP]) Recovery Systems. The GWTP consists of the following components: two 450,000-gallon equalization tanks, three parallel multi-media pressure filters, a UV oxidation reactor, and polished through carbon adsorption tanks. The effluent is discharged to Leon Creek (or used for irrigation at the Kelly Annex Golf Course).

The treatment system has been effective at removing VOCs from the groundwater. UV oxidation is an especially effective treatment for organics at low concentrations. Ultraviolet oxidation is not an effective treatment for arsenic. The GWTP would not provide effective treatment for arsenic, but evaluation of arsenic removal by the GWTP would be needed to assess if system expansion is required for arsenic treatment.

An UV oxidation system would be subject to problems because of fouling from naturally occurring minerals. If the system influent chemical composition changed as the result of system expansion, the pretreatment process may require modification or expansion to control fouling. System expansion may generate more sludge requiring proper disposal. The sludge must pass TCLP, or be treated prior to land disposal.

Ultraviolet oxidation systems tend to have high electrical usage, which leads to increased O&M costs. However, UV oxidation is typically cost-effective when contaminants are difficult or expensive to treat with other treatment technologies. Costs for pre-treatment (for water softening and arsenic removal) are typically moderate, but in this case, would be highly dependent upon the effectiveness of the GWTP as it is currently designed. Overall, costs associated with the use of the GWTP for treating Zone 5 groundwater would depend highly upon the degree of expansion and engineering required to ensure the continued effectiveness of the system. There is the potential to keep costs relatively low (when compared to other ex situ treatment technologies) as long as any additional influent stream is similar in chemical composition to the influent stream for which the system is designed. Due to the complexity of the GWTP, additional maintenance costs would be likely as the result of any change in GWTP operational parameters. Other costs will be dependent upon the amount and size of the hardware (pumps, piping, etc.) required to transport extracted groundwater to the GWTP.

Expansion of the GWTP will be retained for further evaluation because it is effective in the removal of VOCs and is easily implemented. However, consideration must be given to the degree of expansion required, the potential for fouling, pre-treatment, system maintenance, and any off-gas treatment that is not part of the current treatment system."

Site SS003 (S-1) Treatment System. The site SS003 (S-1) Treatment System currently processes extracted groundwater from the S-1 Recovery System. The treatment system consists of the following components: a 1,550-gallon equalization tank, an oil/water separator, a 30-gpm centrifugal influent pump, two sock filters, a 30-gpm low profile tray air stripper, a 30-gpm centrifugal discharge pump, and a 28,000-gallon effluent storage tank. Treated water is collected in the 28,000-gallon storage tank and then discharged to a NPDES-permitted outfall that flows to Leon Creek. The capability of trucking water to the

GWTP for further treatment is available should treatment system effluent levels fall outside of compliance with NPDES discharge requirements.

The interim remedial action for site SS003 (S-1) that was implemented includes collection of an additional 120 gpm with treatment by the SS003 (S-1) air stripper (CH2M HILL, 1998c).

Effectiveness of the system, if operation were changed, would require continued maintenance to remove mineral precipitates and biological growth from the air stripper and for proper operation of the pumps and blowers. Air stripping is not an effective treatment for arsenic and an arsenic removal step may be required prior to air stripping.

Upgrades to the site (SS003) S-1 Treatment System will be retained for further evaluation because the changes can be effective in the removal of VOCs and are easily implemented. Also, it is located in proximity to two of the plumes for which groundwater treatment will be considered. However, consideration must be given to the problem of fouling, any operating costs associated with pre-treatment (water softening, disinfection, etc.), and any off-gas treatment that is not part of the current treatment system.

5.2.2.7 Treated Water Disposal: Discharge. The discharge options surviving the primary technology screening are as follows:

- Discharge to San Antonio POTW
- Discharge directly to surface water

Discharge to the San Antonio POTW were previously discussed under treatment technologies and will not be discussed further.

Discharge Directly to Surface Water. Treated water from ex situ treatment systems could be discharged to the surface water. The most accessible surface water near Zone 5 is Leon Creek, which can be accessed via an existing GWTP Outfall 001A. The existing NPDES and TNRCC permits address surface water discharge through this outfall.

Surface water discharge would be an effective method of disposing of treated groundwater. It is anticipated that a variety of treatment methods could be used to meet discharge concentration limits specified in the permits.

Discharge to surface water would be of moderate cost.

Because it is implementable and cost-effective, discharge to surface water will be retained for the effluent from the treatment system.

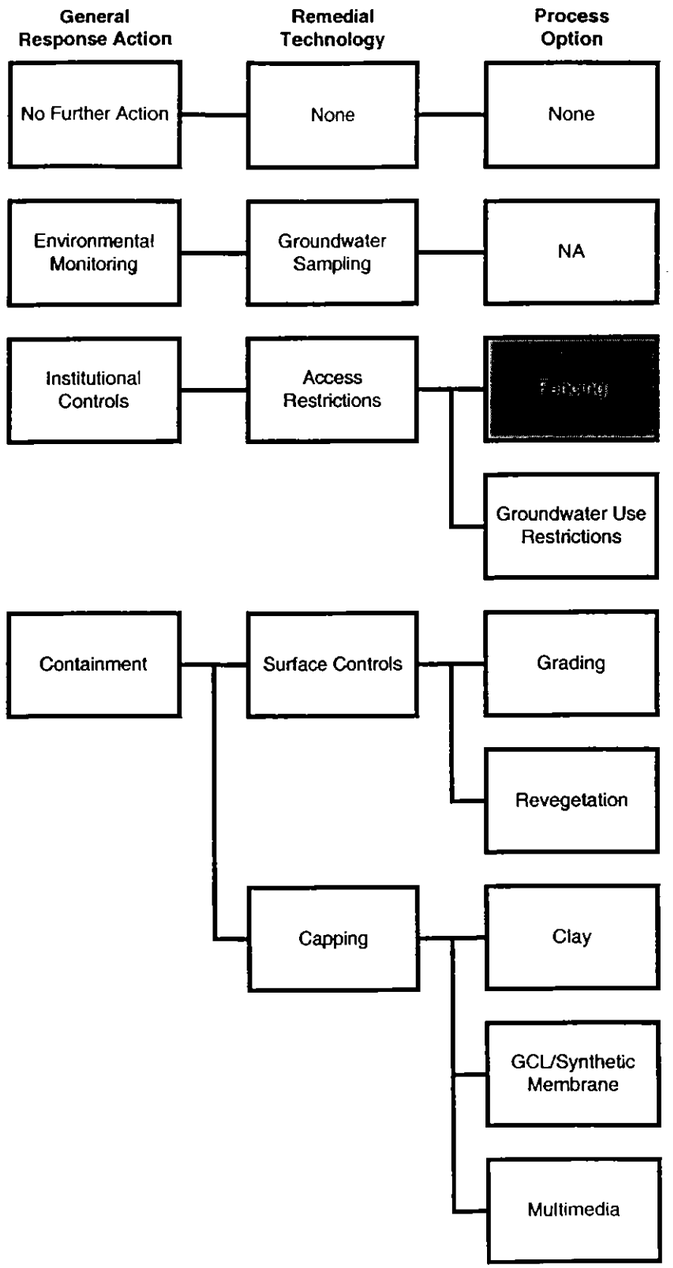
5.2.3 Remedial Technology Screening Summary for Groundwater

The response actions and associated technologies retained (following screening) include the following:

- No further action
- Monitored natural attenuation
- Monitoring

- Institutional controls through shallow groundwater use restrictions
- Containment using vertical extraction wells or collector trenches to establish hydraulic gradients and the use of existing recovery systems
- In situ treatment through air sparging, enhanced biodegradation, or permeable reactive barriers
- Ex situ treatment including UV oxidation for VOC destruction and precipitation and ion exchange, where appropriate, for metals removal
- Discharge to surface water.

Soil Remediation



Shaded box indicates technology is not considered further.

General Response Action	Remedial Technology	Process Option	Description	Technical Implementability Screening Comments	Secondary Screening: Effectiveness	Secondary Screening: Technical and Administrative Implementability	Secondary Screening: Capital/ Operation & Maintenance (O&M) Cost	Comments
No Further Action	None	None	No action.					Required for comparison by NCP; does not meet RAOs.
Environmental Monitoring	Groundwater Sampling	NA		Technically implementable	Good	Good	Low/Low	Used to track the progress of either natural attenuation or active soil remediation.
Institutional Controls	Access Restrictions	Fencing	Restrict access to contaminated soil through fencing.	Technically implementable	Fair	Good	Low/Low	Fencing does not address the remedial objective to minimize leaching. Risks from exposure to surficial soils are less than levels of concern.
		Groundwater Use Restrictions	Restrict groundwater use through restrictive covenants on property deeds.	Technically implementable	Fair	Fair	Low/Low	Does not meet RAOs. Institutional controls do not address the remedial objective to minimize leaching. However, they are needed to control future groundwater use. Must be used in conjunction with other technologies.
Containment	Surface Controls	Grading	Reshape topography to control infiltration, runoff, and erosion.	Technically implementable	Fair	Good	Low/Low	Potentially feasible; typically used in conjunction with capping.
		Revegetation	Add topsoil, seed, and fertilizer to establish vegetation (to control erosion and reduce infiltration).	Technically implementable	Fair	Good	Low/Low	Potentially feasible; typically used in conjunction with other technology.
	Capping	Clay	Place clay over contaminated soils. Includes a cover layer to protect the clay.	Technically implementable	Good	Good	Moderate/Moderate	Potentially feasible; clay cap may inhibit natural attenuation (biological degradation) due to lack of moisture.
		GCL/Synthetic Membrane	Place GCL or synthetic material over contaminated soils; includes a protective cover layer.	Technically implementable	Very good. Can essentially eliminate infiltration.	Good	Moderate/Moderate	Potentially feasible; cap may inhibit natural attenuation (biological degradation) due to lack of moisture.
		Multimedia	Place clay and synthetic combination over contaminated soils.	Technically implementable	Very good. Can essentially eliminate infiltration.	Good	High/Moderate	Potentially feasible; cap may inhibit natural attenuation (biological degradation) due to lack of moisture.

Figure 5.1
Soil Technology/Process Option Evaluation
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Soil Remediation

General Response Action	Remedial Technology	Process Option	Description	Technical Implementability Screening Comments	Secondary Screening: Effectiveness	Secondary Screening: Technical and Administrative Implementability	Secondary Screening: Capital/ Operation & Maintenance (O&M) Cost	Comments
Containment (continued)	Capping	Pavement	Place asphalt for concrete over contaminated soils.	Technically implementable	Fair	Fair	Low/High	Asphalt and concrete caps require relatively high long term maintenance for repair of cracking. Because cap would slow natural attenuation mechanisms, it would be necessary to maintain for decades. Also, pavement may not reduce infiltration to the degree necessary to prevent continued exceedance of groundwater PRGs. While it is true that some asphaltic concrete and concrete caps maintain and perform well over short durations, over the time frame of tens or hundreds of years, maintenance and performance concerns do not compare favorably to clay and synthetic materials. Because clay and synthetic membrane caps are more effective and more durable and lower in long term O&M, pavement caps are not retained.
	Horizontal Subsurface Barriers	Slurry Wall/Grout Curtain	Encapsulate block of soil with grout in conjunction with vertical barriers.	Not applicable to site; horizontal control of groundwater flow is not an objective for this site.				
		Grout Injection	Create barrier by pressure injection of grout.	Not applicable to site; horizontal control of groundwater flow is not an objective for this site.				
In Situ Treatment	Physical/ Chemical	Soil Oxidation	Degrade contaminants by chemical (ozone or hydrogen peroxide), photo, or other oxidation techniques.	Difficult to distribute oxidants in site SS003 (S-1) soils because of high clay content and the presence of two formations of differing permeabilities, the upper primarily clay zone and the lower primarily gravel zone; difficult and expensive to determine effectiveness.				
		Flushing	Wash or flush soil with water or surfactant.	Difficult to distribute water, surfactants, or other solvents in site SS003 (S-1) soils because of high clay content and the presence of two formations of differing permeabilities; difficult and expensive to determine effectiveness.				
		Fixation/ Stabilization	Immobilize contaminants using solidification agents.	In situ solidification is not feasible because of the depth of soil contamination. It is difficult to effectively mix at a depth greater than 10 to 15 ft bgs.				
		Vitrification	Melt/solidify soil matrix using electric currents.	Technically implementable	Potential	Fair	High/NA	Limited commercial applications; very costly technology relative to other technologies; cannot be used for soils below water table.

Shaded box indicates technology is not considered further

FIGURE 5.1
Soil Technology/Process Option Evaluation
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Soil Remediation

General Response Action	Remedial Technology	Process Option	Description	Technical Implementability Screening Comments	Secondary Screening: Effectiveness	Secondary Screening: Technical and Administrative Implementability	Secondary Screening: Capital/ Operation & Maintenance (O&M) Cost	Comments
In Situ Treatment (continued)	Physical/ Chemical (continued)	Vapor Extraction	Extract contaminants by establishing a vacuum.	Technically implementable	Fair	Fair	Moderate/NA	Although the physical removal effectiveness is only fair on CB because of relatively low volatility (Vapor Pressure = 0.1 mm Hg @ 25 degrees F), the addition of air into the soil caused by the SVE system will accelerate biodegradation of the CBs in addition to the volatilization of the target compounds.
In Situ Treatment (continued)	Biological	Natural Attenuation	Natural biological degradation of CBs by aerobic and anaerobic organisms in unsaturated zone.	Technically implementable	Potential	Fair	Low/Low	Potentially feasible.
		Bioventing	Biologically degrade organics through stimulation of aerobic organisms by the addition of oxygen in air.	Technically implementable	Potential	Fair	Low/Low	Potentially feasible.
	Thermal	[redacted]	Inject hot air and recover vapors (a variation of vapor extraction)	Technically implementable	Fair	Poor	Low/High	Typically in situ thermal processes raise the soil temperature to the contaminant boiling point (345 deg for 1,4-DCB). Hot air is not an efficient media to raise soil temperatures this high. Not effective for soil below the water table. Also, it is much more costly than other in situ technologies such as bioventing.
		[redacted]	Inject steam and recover vapors and condensed material (a variation of vapor extraction)	Technically implementable	Potential	Fair	High/NA	Difficult to attain even distribution of steam in site SS003 (S-1) soils because of high clay content and the presence of two formations of differing permeabilities, the upper primarily clay zone and the lower primarily gravel zone. Also much more costly than other in situ technologies such as bioventing.
		[redacted]	Use network of RF transmitters to heat soil, collect vaporized contaminant with vapor extraction system	Technically implementable	Potential	Fair to Good	High/NA	RF heating was piloted at site S-1. Results showed variable effectivenss, likely as the result of the relatively low permeability soils. The effectiveness of this technology is not considered sufficient to justify its relatively high cost.

Shaded box indicates technology is not considered further

Figure 5.1
Soil Technology/Process Option Evaluation
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Soil Remediation

General Response Action	Remedial Technology	Process Option	Description	Technical Implementability Screening Comments	Secondary Screening: Effectiveness	Secondary Screening: Technical and Administrative Implementability	Secondary Screening: Capital/ Operation & Maintenance (O&M) Cost	Comments
Ex Situ Treatment (continued)	Biological	Biological Treatment	Excavated soils are placed on impermeable pad and aerated either by tilling or through a network of air lines.	Technically implementable	Potential	Fair	Moderate/NA	Potentially feasible for contaminated soil. Aerobic biological treatment could be operated as shallow soil depth with tilling providing aeration or in a biopile where air lines are installed to provide oxygen.
	Thermal	Low Temperature Thermal Desorption	Desorb contaminants/treat offgas.	Technically implementable	Potential	Poor	High/NA	Costs high due to low volume. Not cost competitive and would be difficult to implement because of air emission concerns.
		Recycling in Asphalt Plant	Soil added to asphalt mix. Contaminants desorbed as soils are heated and combined with asphalt.	Technically implementable	Potential	Fair	High/NA	Potentially feasible. High clay content makes this alternative unacceptable because asphalt plants will not accept soils with >50% clay for road base asphalt.
		Onsite Incineration	Combust soils at high temperature.	Technically implementable	Good	Poor	High/NA	Not cost competitive with low temperature thermal.
Excavate and Dispose	Onsite	RCRA Subtitle C Landfill	Construct onsite landfill to dispose excavated contaminated soils.	Technically implementable	Good	Poor	High/NA	Relatively small volume makes construction of a hazardous waste disposal unit not cost effective. Also difficult to obtain permit.
		Backfill	Use treated soils to backfill excavations.	Technically implementable	Good	Fair	Low/NA	Potentially feasible; soil must be treated to concentrations below TCLP limits.
	Offsite	RCRA Subtitle C or D Landfill	Remove material for disposal in RCRA Subtitle C or D permitted landfill.	Technically implementable	Good	Good	Moderate/NA	Soils failing TCLP limits are subject to LDRs; disposal in Subtitle C landfill may be applicable for small volumes of soil that fail TCLP limits. Disposal in Subtitle D landfill only for soil that does not fail TCLP limits.

Effectiveness is the ability to perform as part of a comprehensive alternative that can meet RAOs under conditions and limitations that exist at the site.
Implementability is the likelihood that the process could be implemented as part of the remedial action plan under the regulatory, technical, and schedule constraints.
Cost is for comparative purposes only, relative to other processes/technologies that perform similar functions.

Shaded box indicates technology is not considered further

Figure 5.1
Soil Technology/Process Option Evaluation
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Groundwater Remediation

General Response Action	Remedial Technology	Process Option	Description	Technical Implementability Screening Comments	Secondary Screening: Effectiveness	Secondary Screening: Technical and Administrative Implementability	Secondary Screening: Capital/ Operation & Maintenance (O&M) Cost	Screening Comments
Containment (continued)	Groundwater Extraction	Vertical Wells	Standard method for extracting groundwater and establishing hydraulic barriers.	Technically implementable	Good	Good	Moderate/ Moderate	Potentially applicable.
		Collection Trenches	Underground gravel-filled trenches equipped with perforated pipe to collect groundwater.	Potential interferences from buried utilities and limitations on depth. Very effective in heterogeneous aquifers.	Good	Fair	High/Moderate	Potentially applicable.
		Horizontal Wells	Wells drilled horizontally through the aquifer either through directional drilling or horizontally from the bottom of a caisson.	Potentially applicable.	Good	Fair	Moderate/ Moderate	Undulating Navarro Layer could make implementation difficult
	Existing Collection Systems	Recovery System LF012 (D-2), IRP Zone 1	Capture plumes located in the western portion of Zone 5 with existing LF012 (D-2) collection system.	Technically implementable	Good	Good	Low/Moderate	Potentially applicable
		Recovery System LF014 (D-4), IRP Zone 1	Capture plumes located in the western portion of Zone 5 with existing collection system.	Technically implementable	Good	Good	Low/Moderate	Potentially applicable
		Recovery System LF015 (D-5), IRP Zone 1	Capture plumes located in the western portion of Zone 5 with existing collection system.	Technically implementable	Good	Good	Low/Moderate	Potentially applicable
		Recovery System SS042 (CS-2), IRP Zone 2	Capture plumes located in the southern portion of Zone 5 with existing collection system.	Technically implementable, may need augmentation.	Good	Good	Low/Moderate	Potentially applicable
		Recovery System SS042 (CS-2 North Bank), SS002 (ITWP) and WP022 (E-3) IRP Zone 2	Capture plumes located in the southern portion of Zone 5 with existing collection system. SS042 (CS-2 North Bank) wells and WP022 (E-3) wells may be effective.	Technically implementable	Good	Good	Low/Moderate	Potentially applicable for a portion of the plume that migrates southwest into Zone 2.
		Recovery System WP021 (E-1), IRP Zone 2	Capture plumes located in the southern portion of Zone 5 with existing WP021 (E-1) collection trench.	Not applicable. No Zone 5 plumes are within collection system zone of influence.				

Shaded box indicates technology is not considered further.

FIGURE 5.2
Technology Screening
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Groundwater Remediation

General Response Action	Remedial Technology	Process Option	Description	Technical Implementability Screening Comments	Secondary Screening: Effectiveness	Secondary Screening: Technical and Administrative Implementability	Secondary Screening: Capital/ Operation & Maintenance (O&M) Cost	Secondary Screening: Screening Comments
Containment (continued)	Existing Collection Systems (continued)	Recovery System SS003 (S-1), IRP Zone 5	Capture SS003 (S-1) plume located in the northern portion of Zone 5 with existing SS003 (S-1) collection wells.	Technically implementable	Fair	Good	Moderate/ Moderate	Potentially applicable for the SS003 (S-1) plume.
		Recovery System ST006 (S-4), SS038 (S-8), and SS040 (OT-2), IRP Zone 3	Focused on capturing plumes from the eastern portion of Zone 5.	Technically implementable	Fair	Good	Moderate/ Moderate	Potentially applicable.
In Situ Treatment	Physical Treatment	Air Sparging	Air is injected into groundwater through injection wells or trenches. VOCs are stripped and discharged to air or are removed in SVE system for subsequent treatment. May also be used at lower air flow rates to promote biodegradation. Saturated thicknesses and depths to groundwater greater than 5 feet are recommended for successful application.	Potentially applicable. Groundwater levels fluctuate consistently and are often less than 5 feet in thickness. It is likely that trenches would be more effective than injection wells.	Fair	Fair	Moderate/ Moderate	Thickness of the saturated zone and heterogeneity of aquifer impact implementability
		Dual Phase Extraction	A high vacuum system is applied to simultaneously remove gas and liquid for ex situ treatment.	Not applicable. Sites do not have LNAPL contamination (see soil media for smear zone remediation at site SS003 [S-1]).				
		Vacuum Vapor Extraction or In-Well Vapor Stripping	Involves creation of a groundwater circulation pattern and simultaneous aeration within the stripping well to volatilize VOCs from the circulating groundwater.	Not applicable. Shallow aquifers may limit effectiveness due to limited space for reinfiltration/ circulation.				
		Hydraulic and Pneumatic Fracturing Technologies	Involves injection of highly pressurized air to extend existing fractures and create a secondary network of fissures and channels. The enhanced fracture network increases the permeability of the soil to liquids and vapors and accelerates the removal of contaminants, particularly by vapor extraction, biodegradation, and thermal treatment.	Not applicable. The formation does not lend itself to treatment because of the presence of clays.				

Shaded box indicates technology is not considered further.

FIGURE 5.2
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Groundwater Remediation

General Response Action	Remedial Technology	Process Option	Description	Technical Implementability Screening Comments	Secondary Screening: Effectiveness	Secondary Screening: Technical and Administrative Implementability	Secondary Screening: Capital/ Operation & Maintenance (O&M) Cost	Secondary Screening: Screening Comments
In Situ Treatment (continued)	Biological Treatment	Enhanced Biological Degradation	Microbiological degradation, detoxification, and mineralization of hazardous substances, which can be enhanced with respect to electron acceptors, nutrient levels, and pH.	Implementability will be influenced by nature of COCs and heterogeneity of aquifer.	Good	Good	Moderate/ Moderate	Potentially applicable.
		Phytoremediation	Uses plants to clean up contaminated soil and groundwater or to reduce hydraulic gradient through increased evapotranspiration.	Not applicable. Currently no demonstrated field success with chlorinated solvents or arsenic. Depth to groundwater is excessive.				
	Chemical Treatment	Magnetic Separation	Designed to remove inorganics from groundwater by using ion exchange principles to adsorb targeted contaminants onto resin-coated magnetic particles. This technology is best suited for the recovery of radionuclides, heavy metals, and nitrates from groundwater.	Not applicable. No heavy metals present in groundwater.				
		Foams	Involves use of foams to release and mobilize NAPL contaminants in the subsurface, coupled with in situ or ex situ treatment.	Not applicable. Site does not have NAPL contamination.				
		Electrokinetics	Separates and extracts heavy metals, radionuclides, and soluble organic contaminants from saturated or unsaturated soils, sludges, and sediments. An electrical current is applied, which causes electro-osmosis and ion migration. This moves aqueous phase contaminants in subsurface from one electrode to another.	Not applicable. Remediation techniques for low permeability soils. Also, no heavy metals are present.				
		Solvent Extraction	Adds solvents that will dissolve or disperse organic contaminants and remove them from waste.	Not applicable to low CVOC concentrations in groundwater. Would create a potentially larger waste stream to treat.				
		Permeable Treatment Walls	Trench aligned perpendicular to groundwater flow is backfilled with a reactive material such as iron filings to promote abiotic reductive dehalogenation of chlorinated VOCs to harmless byproducts.	Potentially applicable. Potential problem with precipitation clogging the reactive media.	Technology is still being developed, effectivenss is difficult to assess.	Fair	High/Moderate	Potential interference from buried utilities and limitations on depth.
		Iron Colloids	Fe^0 colloids are injected into the contaminated plume. Fe^0 breaks down chlorinated solvents and immobilizes metals.	Potentially applicable. Potential problem with precipitation.	Technology is still being developed, effectivenss is difficult to assess.	Fair	Moderate/ Moderate	Heterogeneous aquifer may affect implementability.
		Chemical Oxidation	Injection of H_2O_2 or other oxidant into groundwater.	Potentially applicable.	Fair	Fair	Moderate/ Moderate	Heterogeneous aquifer may affect implementability.

Shaded box indicates technology is not considered further.

FIGURE 5.2
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Groundwater Remediation

General Response Action	Remedial Technology	Process Option	Description	Technical Implementability Screening Comments	Secondary Screening: Effectiveness	Secondary Screening: Technical and Administrative Implementability	Secondary Screening: Capital/ Operation & Maintenance (O&M) Cost	Secondary Screening: Screening Comments
Ex Situ Treatment	Chemical Treatment	UV/Oxidation	A destructive process that oxidizes organics by the addition of strong oxidizers and irradiation with UV light. The process generates highly reactive radicals that destroy most organic chemical compounds.	Technically implementable	Good	Good	High/High	Potentially applicable.
		Ion Exchange	Removes ions from the aqueous phase by the exchange of cations and anions between contaminants and exchange medium.	Technically implementable	Good	Good	High/High	Potentially applicable for arsenic removal.
		Precipitation	Soluble metal salts are converted into insoluble salts that will precipitate.	Technically implementable	Good	Good	Moderate/ Moderate	Potentially applicable for arsenic removal.
		Surfactants/ Cosolvents	Reduces pump and treat volumes by mobilizing and /or solubilizing NAPLs. Uses surfactants with both polar and nonpolar regions.	Not applicable. NAPL contamination is not present.				
		Selective Colloid Mobilizations (SCM)	The SCM suspends colloids and the attached contaminants in an aquifer, which are then pumped to the surface and settle as solids.	Not applicable. Still in developmental stages.				
		Regenerative Thermal Oxidizers	These systems destroy VOCs and other hazardous air pollutants by raising the oxidation temperature and maintaining it with oxygen for 0.5-2.0 seconds. The VOCs are oxidized to carbon dioxide and water and are discharged to the atmosphere.	Not applicable. Designed for high air volumes.				
		Catalytic Oxidizers	A thermal oxidizer that incorporates a temperature-controlling burner and a catalyst section - with the objective of reducing the temperature needed to break down the organic contaminant.	Not applicable. Chlorinated hydrocarbons may poison catalyst. Special construction materials needed to prevent corrosion by HCL.				
		Hydrolysis	Destruction of contaminant through hydrolytic breaking of chemical bonds at elevated pH.	Not applicable. Requires excessively high temperature to aid in breaking the chemical bonds.				

Shaded box indicates technology is not considered further.

FIGURE 5.2
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Groundwater Remediation

General Response Action	Remedial Technology	Process Option	Description	Technical Implementability Screening Comments	Secondary Screening: Effectiveness	Secondary Screening: Technical and Administrative Implementability	Secondary Screening: Capital/ Operation & Maintenance (O&M) Cost	Secondary Screening: Screening Comments
Ex Situ Treatment (continued)	Chemical Treatment (continued)	Electrochemical Reduction	Electrochemical treatment changes the oxidation state of ions in solution to a preferred and treatable state through the application of an electrolyte solution. Generally used to precipitate heavy metals.	Not applicable. Heavy metals are not COCs for this site.				
	Physical Treatment	Air Stripping	Large volumes of air are forced through wastewater in a packed column, or by diffused aeration to promote transfer of volatile contaminants to the air.	Technically implementable	Good	Good	High/Moderate	Potentially applicable. Off-gas treatment may be required.
		Oil-Water Separation	Oil separated from water by gravity. Treatment may be required for dissolved or emulsified oil prior to simple physical separation.	Not applicable. Oil is not present.				
		Flotation	Gas, dissolved under pressure, is released at normal pressure as fine bubbles into the wastewater and attaches to suspended solids, free and emulsified oils, and grease, floats to the top, and is skimmed off.	Not applicable. Suspended solids and oils are not present.				
		Media Filtration	Fine particles are removed from liquid stream by a filter medium. Common media are sand, diatomite, coal, natural or synthetic fabric, and wire cloth.	Not applicable. Fines are not present.				
		Adsorption	Contaminated groundwater passed through adsorbent such as granular activated carbon. The adsorbent is regenerated or replaced regularly.	Potentially applicable.	Fair	Good	High/Moderate	Not effective for removal of CVOCs
		Membrane Processes	Barrier membrane preferentially passes some components of a fluid mixture or solution.	Not applicable. May not remove organic contaminants from groundwater.				
		Steam Stripping	Similar to air stripping but steam is pumped into the stripping column. The heat promotes transfer of volatile contaminants from liquid to air.	Not applicable. Suited primarily for removal of difficult to strip contaminants at high concentrations. These conditions are not present at this site.				

Shaded box indicates technology is not considered further.

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Groundwater Remediation

General Response Action	Remedial Technology	Process Option	Description	Technical Implementability Screening Comments	Secondary Screening: Effectiveness	Secondary Screening: Technical and Administrative Implementability	Secondary Screening: Capital/ Operation & Maintenance (O&M) Cost	Screening Comments
Ex Situ Treatment (continued)	Biological Treatment	Bioreactor Systems	Processes contaminants through a packed tricklebed reactor system.	Technically implementable	Fair	Fair	Moderate/ Moderate	Not applicable to low concentration plumes.
		Aerobic Processes	Organics in wastewater oxidized through the use of a mixed culture of organisms in aerobic conditions.	Not applicable. There is insufficient organic substrate to sustain organisms.				
		Anaerobic Processes	Organics in wastewater oxidized through the use of a mixed culture of organisms in anaerobic conditions.	Not applicable. There is insufficient organic substrate to sustain organisms.				
	Existing Treatment System	Environmental Pollution Control Facility (EPCF)	Organics in wastewater oxidized through the use of a mixed culture of organisms in aerobic conditions at the existing EPCF.	Technically implementable	Good	Fair	Low/Uncertain	Potentially applicable. Does not have the capability to treat CVOCs.
		San Antonio POTW	Organics in wastewater oxidized through the use of a mixed culture of organisms in aerobic conditions at the POTW, commingled with municipal sewage.	Technically implementable	Good	Fair	Low/Uncertain	SAWS may not have capability to treat CVOCs.
		Zone 1 Groundwater Treatment Plant (GWTP)	Treatment includes filtration, pH adjustment, and UV/oxidation with H_2O_2. Recovery systems LF012, LF014, and LF015 (D-2, D-4, and D-5) with discharge via EPCF, eventually Leon Creek (on EPCF NPDES permit).	Technically implementable	Good	Good	Low/Low	Potentially applicable.
		Zone 2 GWTP	Treatment includes oil/water separation, flocculation, filtration, ion exchange, UV oxidation with H_2O_2, and neutralization. Recovery systems WP021, WP022, SS042, and SS002 (E-1, E-3, CS-2, CS-2NB, and IWTP, respectively) with discharge via EPCF, eventually Leon Creek (on EPCF NPDES permit).	Technically implementable	Good	Good	Low/High	Potentially applicable. Currently has some excess capacity.
		Zone 5 S-1 Treatment System	Treatment includes filtration and air stripping. Recovery system KY029 (S-1) with discharge to a 28,000 gallon holding tank with subsequent discharge to the sewer or Outfall 007.	Technically implementable	Good	Good	Low/High	Potentially applicable. Air stripper not utilized at full capacity.
		Zone 3 GWTP	Treatment includes oil/water separation, neutralization, flocculation, filtration, ion exchange, clarifier, and UV oxidation with H_2O_2. Recovery systems MP, S-6, S-8, S-4 with discharge via EPCF, eventually Leon Creek (on EPCF NPDES permit).	Technically implementable	Good	Good	Low/High	Potentially applicable. However, limited capacity remaining and possible future expansion of the recovery system is yet to be determined.

Shaded box indicates technology is not considered further.

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Groundwater Remediation

General Response Action	Remedial Technology	Process Option	Description	Technical Implementability Screening Comments	Secondary Screening: Effectiveness	Secondary Screening: Technical and Administrative Implementability	Secondary Screening: Capital/ Operation & Maintenance (O&M) Cost	Secondary Screening: Screening Comments
Discharge	Discharge	EPCF	Discharge of groundwater to the Industrial Waste Collection System of the EPCF.	Technically implementable	Good	Good	Low/Uncertain	Potentially applicable.
		San Antonio POTW	Discharge of groundwater to the San Antonio sanitary sewer collection system.	Technically implementable	Good	Fair	Low/Uncertain	Potentially applicable.
		Surface Water	Discharge of treated groundwater to storm sewers.	Technically implementable	Good	Good	Low/Low	Potentially applicable.
		Injection	Reinjection of treated groundwater to the shallow zone aquifer upgradient or side gradient to the plume.	Not applicable. Modeling results (Appendix G) indicate that reinjection would have a minimal affect on the remediation time frame and the additional capital investment could not be justified.				
		Effluent Polishing System	Discharge groundwater via EPS (under construction). Use common effluent tank for holding with discharge to EPCF, eventually Leon Creek (on EPCF NPDES permit).	Technically implementable	Good	Good	Low/Low	Potentially applicable.

Shaded box indicates technology is not considered further.

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SECTION 6.0

Development and Screening of Alternatives

6.1 Alternative Development for Groundwater

6.1.1 Methodology of Groundwater Alternative Development

The process for developing the groundwater remediation alternatives is outlined in Figure 6.1. Development of groundwater remediation alternatives involved integration of plume-specific remediation options with contaminant-specific technologies.

The contaminant-specific options are developed in Section 6.1.2 and consider remedial technologies that are appropriate for each COC without regard to the specific contaminant plume. The contaminant-specific alternatives draw on the GRAs and technology screening discussed in Sections 5.1. The contaminant-specific options are then used to formulate remediation options for each contaminant plume.

The plume-specific options, presented in Section 6.1.4, are based on contaminant-specific technologies and consider the placement of potential remedial actions with respect to the location and movement of each contaminant plume. The nature and extent of contamination (Section 3.2.2), fate and transport modeling (Section 3.2.3), and RAOs (Section 4.3) are used to develop the locations for implementing GRAs (Section 5.1.2). The plume-specific options are then evaluated on the basis of implementability, effectiveness and cost. Based on this evaluation, plume-specific remediation options are either eliminated or carried forward for further evaluation.

Specific remediation options for each plume that survive the evaluation in Section 6.1.4 are combined into several alternatives for groundwater remediation in Zone 5. These alternatives are discussed in Section 6.2.

6.1.2 Contaminant-Specific Alternatives for Groundwater

This section discusses the specific technologies available for treating each of the COCs. These alternatives were developed from the options that were carried forward from Section 5.0.

6.1.2.1 Arsenic

In Situ: There is no well-developed method for in situ arsenic remediation. It is likely that arsenic is present due to reduction of naturally occurring arsenic in the aquifer sediments because of the anoxic conditions generated by microbial decay of the associated organics. It is present only in the reducing portion of the plumes and is not mobile in the aerobic portions that are migrating off base. It is likely that arsenic would oxidize to the less mobile As (V) as the anoxic conditions are eliminated during remediation of the organic contaminant such as benzene and CB. No in situ remediation alternative is developed.

Ex Situ: Low levels of arsenic contamination are present in a few areas in the shallow groundwater of Zone 5. The maximum detected concentration of arsenic is 85.6 µg/L. Groundwater extracted from all of the plumes and combined for treatment in one process would effectively reduce arsenic contamination to below the MCL (50 µg/L). Nevertheless, if arsenic concentrations in the discharge were ever to reach levels of concern, the most common method of arsenic removal from water could be instituted. It consists of the oxidation of As (III) to As (V), precipitation of As (V) with ferric ion, followed by flocculation and filtration. Residual amounts of As (V) could be removed with ion exchange.

6.1.2.2 Chlorobenzene

In Situ: CB can be remediated in situ by stimulating aerobic microbial degradation. Depending on specific site conditions, microbial activity can be stimulated by the introduction of oxygen and, if necessary, nutrients into the groundwater.

Ex Situ: The method implemented as recommended in the focused FS (CH2M HILL, 1998c) is dual phase extraction of the groundwater and SVE of the contaminated soil.

6.1.2.3 Chlorinated Volatile Organic Compounds

In Situ: CVOCs can be remediated in situ by stimulating aerobic co-metabolic microbial degradation. Depending on specific site conditions, microbial activity can be stimulated by the introduction of oxygen, secondary substrates, and nutrients into the groundwater. Flow through reactive walls using zero valent iron are also used to remediate CVOCs.

Ex Situ: CVOCs can be treated ex situ either by air stripping or UV oxidation. UV oxidation has the advantage over air stripping of not requiring an off-gas treatment system. In the event that air emission controls were implemented for air stripping, UV oxidation could be more cost competitive, although a detailed cost evaluation of UV oxidation versus air stripping was not performed.

A detailed cost evaluation at this point was not possible because the Zone 5 treatment system flow rate is widely variable, depending on which alternative is selected, and the cost comparison is very sensitive to flow rate. This is because for low flow rate alternatives there may be no capital cost for the UV/OX system, favoring UV/OX. At higher flow rates, the capital cost and high O&M of the UV/OX system results in air stripping being more cost effective. As a result, the detailed cost comparison should be performed in design when the flow rate is known more precisely. UV oxidation was selected as a representative process option for the purpose of estimating treatment system costs, but air stripping will be re-considered during pre-design.

6.1.3 General Design Information

Many elements of the conceptual design of remediation systems are common to all systems regardless of location. These common elements include construction, operation, and environmental monitoring activities, which are discussed in this section. Section 6.1.4 provides the plume-specific conceptual designs.

6.1.3.1 Extraction Wells and Collector Trenches

Extraction wells would be drilled to the top of the Navarro Group and screened through the entire depth of the shallow aquifer. A dedicated pump would be installed in each well with piping used to convey the extracted groundwater from the wells to the treatment system.

Collector trenches would be approximately 2 ft wide and would be keyed into the Navarro Group. Collection sumps would be installed in the bottom of the trench, which would be sloped about 1 to 2 percent into the sumps. Perforated pipe would be placed in the bottom of the trench to convey collected water to collection sumps. The excavation would then be backfilled with coarse sand or gravel to promote collection of the water.

Well and collector trench locations, spacing, and production rates were established using a groundwater flow model (see Appendix G). This modeling is considered adequate for a first order approximation of remedial action alternatives. Future design efforts may be required to further refine the model to better reflect actual conditions in the study area. Optimization of the extraction system (including the selection of wells as opposed to trenches) would be made based on model refinements during remedial design.

Injection of treated groundwater was considered as a means of achieving accelerated cleanup times compared to extraction, treatment and discharge. Modeling (Appendix G) indicated that injection of the treated groundwater had only a marginal affect on treatment times and injection was not considered any further except for delivery of substrates and/or nutrients as discussed in Section 6.1.3.2.

The time to achieve cleanup of the groundwater is the total time needed for the contaminants in the aquifer sediments to move from the sediments into the groundwater, plus the time for the groundwater to move from the upgradient edge of the plume to the extraction wells or trenches.

The groundwater flow model (Appendix G) estimates the length of time for the groundwater to move from the upgradient edge of the plume to the extraction wells or trenches.

The time required for the contaminants to move from the aquifer sediments into the groundwater, t_c, was calculated from:

$$t_c = PV \cdot t_{pv}$$

where PV is the number of pore volumes that must be circulated through the contaminated zone to achieve cleanup, and t_{pv} is the time required for movement of one pore volume through the contaminated area.

The number of pore volumes was from the EPA batch flushing model. The solution to the EPA batch flush model (Zheng et al., 1991 and Zheng et al., 1992) is:

$$PV = -R \cdot \ln\left(\frac{C_{wt}}{C_{wo}}\right)$$

where PV is the number of pore volumes of clean water that must be circulated through the contaminated zone to reduce the concentration from the initial contaminant concentration in the groundwater, C_{wo}, to C_{wt}, the concentration of the cleanup standard; and R is the retardation coefficient for the target constituent, estimated from the following equation:

$$R = 1 + \frac{K_{oc} \cdot f_{oc} \cdot \rho_b}{n}$$

where K_{oc} is the organic carbon partition coefficient; f_{oc} is the fraction of organic carbon in the aquifer sediments; ρ_b is the bulk density of the aquifer material; and n is the aquifer porosity. The retardation factor was calculated from the values for bulk density, fraction of organic carbon and the partition and K_ds found in Appendix G. A porosity of 0.4 was used and was taken from the RI report (CH2M HILL, 1999).

The time required for one pore volume to move through the aquifer, t_{pv}, was estimated by dividing the volume of groundwater in the contaminated zone by the pumping rate of the remediation system. The volume of the contaminated groundwater was estimated from the product of the area of the plume, the saturated thickness, and the porosity. The pumping rate was taken from the flow model (Appendix G).

The batch flushing model does not account for heterogeneities, the presence of NAPLs, and leachate from the original source of contamination (National Research Council, 1994) and the time to achieve cleanup of the aquifer is probably underestimated. Nevertheless, the timeframe so estimated would indicate the minimum time to achieve cleanup and is useful from that standpoint. For the purposes of estimating the cleanup times for this CMS, the number of pore volumes needed to flush the aquifer was calculated from the above equation and doubled.

6.1.3.2 In Situ Degradation

In an in situ enhanced biodegradation system, a substrate and/or nutrient solution is injected into the groundwater plume to permeate the aquifer and promote the growth of microbes to bioremediate the contamination. Substrates and/or nutrients would be mixed with water that has been extracted downgradient. The mixture of nutrients and groundwater would be injected upgradient to stimulate co-metabolism of the chlorinated solvents in the aquifer. Methanol, hydrogen peroxide, and other electron acceptors can be used to stimulate growth of aerobic microorganisms for degradation of the less highly chlorinated compounds.

Because both PCE and TCE are present in Plume D, enhanced in situ bioremediation would be implemented there by anaerobic/aerobic sequential biodegradation (Vogel, 1994). In the first step, PCE would be degraded to mono-, di- and trichlorinated products through anaerobic reductive dechlorination. In the second step, the degradation products resulting from the first step, plus the TCE that was initially present, would be aerobically co-metabolically reduced.

Implementation of an in situ enhanced biodegradation system would require the installation of extraction and injection wells and/or trenches to infuse the aquifer and groundwater plume with substrate and/or nutrients. Testing of the aquifer would be

required prior to producing a detailed design. Wells and trenches would be constructed in the same fashion as extraction wells and trenches as described in Section 6.1.3.1.

A delivery system capable of supplying a solution at the appropriate rate to all the wells and trenches would also be required for implementation of this option. A solution of water and nutrient would be mixed at a central facility, transported to the injection site via ordinary PVC piping, and injected into the aquifer at the appropriate rate. The amount and concentration of nutrient solution would have to be determined based on aquifer properties and the oxygen utilization rate of the microorganisms in the presence of nutrient solution and contamination. Extensive bench and field testing would be required to assess aquifer properties and treatment effectiveness. Bench scale testing would be required to help estimate required concentration of nutrient and corresponding biodegradation rate.

A recovery system, water storage tank, nutrient storage tank, mixing tank, transfer pump, control system, piping, and injection system would be sized according to the required substrate and/or nutrient concentration and injection rate. The water supply would be extracted groundwater. Injection of water into the aquifer would require that the water first be treated to remove contaminants down to MCLs. The groundwater treatment system would be a centralized treatment system, and would be the same one used for ex situ treatment of the groundwater (see Section 6.1.3.3). Physical location of the recovery and injection system would ultimately be determined based on logistical requirements and aquifer properties.

Flow modeling (Appendix G) indicates that injection of about half of the volume of the extracted water is needed to maintain proper groundwater gradients. The other half of the extracted water would be treated and discharged as described in Section 6.1.3.3.

Since the mechanism for biodegradation varies with the contaminant, the design of an in situ biodegradation system must be specific to the contaminants present in the plume to be remediated. Reductive dechlorination, which is the initial step for the degradation of PCE, would require electron donors. DCE, a degradation product of reductive dechlorination, and CB would require oxidation to be degraded.

Bioremediation systems produce little or no waste and eliminate the source of contamination, rather than prevent its migration. Typically, all waste generated is associated with the installation and operation of hardware used for nutrient injection. No waste is created during the actual biodegradation process and residuals from the process are inert. Operation of an in situ enhanced biodegradation system would be partially automated. Nutrient solution flow would be regulated with a flow control system that would monitor hydraulic mounding in the injection system and adjust the flow as needed. Nutrient solution mixing could be accomplished manually in a batch mode or automatically with an online injector that would add nutrients to the water at pre-set amounts and intervals. Maintenance and the adjustment of system operational parameters would be required periodically. Once in operation, labor requirements would be low compared to other ex situ treatment technologies.

The rate of in situ biodegradation depends on many factors, including the physical and chemical conditions that are present in the aquifer. These factors affect, among others, the interactions between the water, aquifer matrix, microbes, and nutrients. In addition to aquifer characteristics, the effectiveness of the alternative depends upon the adequacy of the nutrient injection system for even nutrient distribution, and the time required for

degradation of COCs down to acceptable levels. Testing would be required to determine the most appropriate method of in situ remediation and to determine the optimal design parameters.

So that remedial options for each plume could be compared, the rate of enhanced biodegradation was estimated. Many of the factors that affect the rate at which bioremediation proceeds are unknown, including the concentration contaminants in the aquifer sediments. For the purposes of this CMS, the time to achieve cleanup of the aquifer and groundwater through bioremediation was estimated as the time required for the contaminants to undergo 10 half lives of biodegradation. The biodegradation half lives were taken from the RI report (CH2M HILL, 1999). PCE was assumed to undergo anaerobic decay while the other contaminants were assumed to undergo co-metabolic decay by aerobic microbes.

System cost is primarily dependent upon the hardware, well installation and nutrient requirements. Periodic maintenance costs associated with maintenance of the nutrient injection system and well conditioning (to prevent microbial fouling of well screens) can be anticipated.

As described in the Plume A FFS (CH2M HILL, 2001), alternatives were built around three insitu treatment technologies, flow through reactive walls, insitu oxygen treatment and anaerobic cometabolic bioremediation. Each of these technologies are briefly described for the development of Plume A alternatives only.

Flow-through Reactive Walls

Flow-through reactive walls, or treatment walls, are structures installed underground to treat contaminated groundwater. Treatment walls are put in place by first constructing a trench across the flow path of contaminated groundwater. The trench is then filled with a chosen material based on the types of contaminants found at a site. As the contaminated groundwater flows through the treatment wall, the contaminants are chemically changed into less toxic or nontoxic substances.

For chlorinated solvents, zero valent iron (ZVI) is the most commonly used treatment material. The ZVI (typically iron filings) will chemically reduce and strip off the chlorines from the solvents, converting them to harmless ethene.

Reactive barriers can effectively treat the water that passes through them, but they cannot treat pollutants that are already downstream of the installation. The downgradient dissolved pollutants will eventually be evaluated in the CMS. By placing many parallel walls in a contaminated area, it may be possible to speed up the entire area's cleanup. Reactive walls could potentially be used as both a source control measure and as a remedial solution to treat contaminated groundwater before it flows off base.

This technology delivers ZVI into groundwater systems by injecting reactive slurry containing colloidal-sized ZVI, water, and nitrogen gas. The reactive slurry is injected into the aquifer via wells and treatment takes place below the ground surface. The nitrogen gas pressurizes the slurry for injection and maintains subsurface anaerobic conditions to ensure that the ZVI is not oxidized before it is delivered to the target treatment zone. As the contaminated groundwater flows through the treatment zone, the chlorinated solvents are chemically changed into less toxic or nontoxic substances.

To be effective, reactive slurry injection requires wells typically placed every 25 feet or less to clean up an area.

In-situ Oxygen Treatment.

In situ, or in place, oxygen treatment is a technology that uses chemicals to treat contaminated soils and groundwater. The chemicals are injected into the aquifer via wells and treatment takes place below the ground surface.

Two common compounds used for *in situ* oxidation are hydrogen peroxide and potassium permanganate; both can be used to treat the solvents present in shallow groundwater. Once the pollutants come into contact with the oxidizing chemicals, they are turned into carbon dioxide or less toxic or nontoxic substances though chemical reactions.

To be effective, *in situ* oxidation requires that relatively large amounts of oxidizing chemicals be injected into the ground. Injection wells typically must be placed every 100 feet or less to clean up an area. Typically, the chemicals must be reinjected twice for the process to be effective. Disadvantages of oxidation may include heat and gas generation, and the treatment may be detrimental to the native bacterial population.

Enhanced microorganism breakdown (or biodegradation) is a treatment process for groundwater contamination. Enhanced biodegradation uses naturally occurring microorganisms (bacteria) to degrade, or break down, hazardous substances into less toxic or nontoxic substances. Microorganisms, just like humans, digest organic substances for nutrients and energy.

To speed up the natural breakdown of fuels or solvents, technologies are available that help create favorable environmental conditions for the microorganisms to digest the contaminants. For chlorinated solvents, two types of enhanced biodegradation can be used: aerobic cometabolism and anaerobic reductive dehalogenation. With aerobic cometabolism, other organic compounds (such as methane or propane) are injected into the groundwater along with oxygen to accelerate the biodegradation of the chlorinated solvents. The microorganisms digest and grow using the added organic compounds. They digest the chlorinated solvents when the added organic compounds are gone.

With anaerobic reductive dehalogenation, more complex organic compounds (e.g., vegetable oil or molasses) are added without oxygen. The microorganisms digest the complex organics and use up any remaining oxygen. Under these conditions, the microorganisms may respire ("breathe") the chlorinated solvents, since oxygen is not present. The chlorine atoms are removed from the chlorinated compounds in steps and the eventual result is harmless ethene. However, during the process, byproducts may accumulate from TCE degradation; these include DCE and vinyl chloride. The byproducts themselves will eventually be degraded.

To be effective, both enhanced biodegradation processes require that relatively large amounts of the organic supplements be injected into the ground. Injection wells typically must be placed very closely (e.g., every 25 feet or less). The organic compounds must be re-injected every six months, and the entire process can take up to two years to complete.

Methane or propane (aerobic cometabolism) injection was not considered feasible because of public safety issues and low probability of success. Therefore, the alternatives developed

in Section 6.0 consider the use of vegetable oil (anaerobic cometabolism) for enhancing natural biodegradation processes.

6.1.3.3 Ex Situ Treatment System

The construction of the ex situ treatment systems would consist of connecting modular units, for precipitation and ion exchange (if necessary), and UV oxidation systems. Treatment systems would be sized based on a combination of extraction flow rates and desired treatment flow rates.

Air emissions are generally not of concern with the use of UV oxidation systems because the VOCs are degraded to salts, carbon dioxide and water. Sludge and other solid waste that may be generated would be disposed of at the appropriate disposal facility. The NPDES permit requirements would be adhered to, or the permit would be revised to account for additional flows from any of the treatment systems to the outfall leading to Leon Creek.

Limitations of the UV oxidation system include interferences from high turbidity and high suspended solids concentrations in the groundwater. Also, the waste stream should be relatively free of metal ions (less than 10 mg/L) and insoluble oil or grease to minimize the potential for fouling of the UV quartz sleeves. High alkalinity and carbonates in the groundwater may also cause fouling of both the reactor vessel and the UV quartz sleeves. The groundwater data for Zone 5 indicates that pre-treatment may be required to remove these interferences. Where appropriate, precipitation/filtration and ion exchange would be used to remove metals and/or arsenic.

The effectiveness and implementability depends on many factors including the physical conditions that are present in the aquifer. Limitations of the effectiveness of extraction systems always relate to the accuracy of the hydrogeological parameters used in design. Changes and uncertainties in the hydraulic conductivity, gradient, or thickness can affect the ability to fully intercept the contamination plume. Treatment of the extracted groundwater could remove more than 99 percent of the COCs from the extracted water. Reduction of contamination in the study area would depend on the effect of the pump and treat system on local hydrology, the sorption and solubility of contaminants to the aquifer materials, and the amount of contaminant migration from source(s) to the groundwater.

Operation of the pump and treat systems would be automated and the system would run on a continuous basis. Daily surveillance should be performed to ensure that the system is running properly and to gather data. A routine maintenance program should be established.

Pump and treat systems usually take several months to design and install, but should halt the migration of contaminated groundwater immediately upon startup. System cost is primarily dependent upon the hardware and well installation. Periodic maintenance and waste disposal costs can be anticipated. Overall costs are low compared to other, more mechanically complex treatment systems.

6.4.3.4 Environmental Monitoring

The objective of this environmental monitoring program is to assess the degree and effectiveness of the remedial actions. Environmental monitoring (sampling) would be

performed to monitor the reduction in PCE, TCE, 1,2-DCE, CB, and arsenic contamination levels.

Initially, groundwater monitoring samples would be collected at the same locations and frequencies as currently done. Eventually, groundwater monitoring activities would be reduced as contamination levels drop in response to the remedial actions.

6.1.3.5 GWTP Upgrades

The remediation groundwater modeling results (Appendix G) indicate that some of the contaminant plumes will eventually migrate from Zone 5 into Zones 2 and/or 3. Some of the plumes would be entirely captured by the existing recovery systems while others would require the addition of a few more recovery wells or trenches in the vicinity of existing recovery systems.

In general, the placement of the wells and trenches is based on the goal of preventing further migration of contaminants from the study area. Direction of groundwater migration and concentrations of COCs were both factors in the expansion of the existing recovery systems.

It is also assumed that the excess capacity of the GWTP can be utilized.

6.1.3.6 Monitored Natural Attenuation

Natural attenuation relies on the groundwater's natural ability to lower contaminant concentrations through physical, chemical, and biological processes until cleanup levels are met. It occurs without regard to human action or inaction, and thus is, by default, a component of the No Action Alternative. A natural attenuation response action generally includes monitoring to track the direction and rate of movement of the contaminants, as well as responsibility for maintaining effective, reliable institutional controls in the interim to prevent use of the contaminated groundwater.

Both no action and monitored natural attenuation achieve remediation objectives in the same manner. Both use a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. To ensure that remediation objectives are being achieved, natural attenuation requires performance monitoring. However, the No Action Alternative does not include performance monitoring (USEPA, 1997).

Natural attenuation of groundwater constituents at Kelly AFB has been documented at Site S-4 (HydroGeoLogic, 1990), Site S-1 (PES, 1998), and at other locations in Zone 5. Data gathered by HydroGeoLogic for the fate and transport simulations of plumes in Zone 5 suggest that constituents are degrading and that many plumes will attenuate to MCLs by the time they reach the base boundary (Appendix G).

6.1.4 Plume-Specific Remediation Options

This section identifies plume-specific remediation options and compares them on the basis of effectiveness, implementability and cost. The contaminant plumes are identified in Figure 3.10 and labeled A through K. The options considered include monitored natural attenuation, in situ remediation using enhanced biodegradation, and containment by

establishment of hydraulic barriers. Those options that survive this screening process are combined into the Zone 5 remediation alternatives discussed in Section 6.2.

Plume-specific remediation options where developed based on the general location of the remediation system with respect to the contaminant plume being addressed. Remediation systems are located at or near the source area, at the region at which contaminant concentrations drop to MCLs (plume perimeter), at the base perimeter, or off base. With regard to groundwater remediation, the term "source control" is used to designate groundwater remediation of the "source area" (as defined in Section 3.2.2) and is referred to as "source control."

For the purposes of evaluating plume-specific options, a centralized groundwater treatment system with a capacity of 400 gpm was used. The central treatment facility and associated piping is shown in Figure 6.2. Capital and operating costs for the central treatment facility and associated piping are allocated to each plume based on flow rates. When remediation options are combined into alternatives (Section 6.2), the 400 gpm treatment system assumed here is replaced by a treatment system sized with a capacity that is matched to the specific needs of each alternative. The cost evaluation presented in Section 7.3.7 is based on the costs for the matched treatment systems, not on the 400 gpm system.

General design information is discussed in Section 6.1.3. Tables 6.1 through 6.7 present specific design parameters for each of the remediation options considered for each of the plumes. The corresponding conceptual designs are shown in Figures 6.3 through 6.11. Details of the cost estimate for each option are provided in Appendix J.

6.1.4.1 Remediation Options for Plume A

A Zone 5 FFS for Source and Perimeter Control for Plume A was finalized in October 2001. An investigation was conducted for Plume A in February 2001. The results of the investigation indicate that at most boring locations the thickness of the shallow aquifer is not sufficient to support a majority of the alternatives previously discussed in Section 5.0 of the report. Based on the investigative work, the FFS presented three alternatives: no action, in situ oxygen treatment at Plume A source area with a permeable reactive barrier along the perimeter, and anaerobic cometabolic bioremediation at Plume A source area with a permeable reactive barrier along the perimeter of the installation. These remediation options are discussed in the following paragraphs for the source area, perimeter area, and the off base area.

Source area: At the source area in Plume A, in situ treatment is the most effective alternative. In situ, or in place, oxygen treatment is a technology that uses chemicals to treat chlorinated soils and groundwater. The chemicals are injected into the aquifer via wells and treatment takes place below ground surface.

Enhanced microorganism breakdown (or biodegradation) is a treatment process for groundwater contamination that will also be evaluated as part of an alternative for source control for Plume A. Enhanced biodegradation uses naturally occurring microorganisms (bacteria) to degrade, or breakdown, hazardous substances into less toxic or nontoxic substances.

Perimeter area: As discussed in the FFS for Plume A, only flow-through reactive walls will be evaluated along the perimeter of the base to intercept groundwater flux within the

contaminant plume before it exits the installation. Flow through reactive walls, or treatment walls are structures installed underground to treat contaminated groundwater. Treatment walls are put in place by first constructing a trench across the flow path of the contaminated groundwater. The trench is then filled with a chosen material based on the types of contaminants found at the site. For chlorinated solvents found at Plume A, zero valent iron (ZVI) is the most commonly used treatment material. The ZVI (typically iron filings) will chemically reduce and strip off the chlorines from the solvents, converting them to harmless ethene.

Off base area: For the off base component, only monitored natural attenuation was evaluated. It is unknown how long it would take to reach PRGs under this option. Pump and treat treatment is not a viable option because of hydraulic conditions.

6.1.4.2 Remediation Options for Plume B

See Section 9.0 for a discussion of Plume B.

6.1.4.3 Remediation Options for Plume D

Source area: Of the three alternatives, the in situ treatment and containment with ex situ treatment options would be the most effective, each meeting PRGs in 20 to 30 years (Table 6.2). The other option, monitored natural attenuation, would take almost 30 years to reach PRGs. The active remediation systems are effective in reducing the time frame for achieving PRGs because there is potentially a source term that is continuing to contaminate the groundwater (Appendix G). As discussed in Appendix G, modeling results showed that the potential source is likely less than 5 years old and may be continuing.

The total life cycle cost of the in situ treatment option is in line with the other active remediation option, containment with ex situ treatment. Even though both alternatives would be designed to operate to meet PRGs for 16 years, there is some uncertainty as to the length of time, as explained in the Plume A source area discussion. Because of this, both the in situ and containment with ex situ treatment options will be carried forward for further evaluation. The monitored Natural Attenuation Alternative represents the least expensive alternative and will be carried forward for further evaluation.

Plume perimeter area: For the perimeter area of Plume D, only monitored natural attenuation and containment with ex situ treatment were evaluated for the same reasons as described for the perimeter area component of Plume A. As indicated on Table 6.2, containment with ex situ treatment would meet PRGs in less time than monitored natural attenuation. However, monitored natural attenuation is significantly less expensive than the containment with ex situ treatment option. Furthermore, Plume D could be fully captured by the upgraded SS042 (CS-2) recovery system, discussed below, at a significant cost saving. For this reason, only the monitored natural attenuation and containment with ex situ treatment option will be carried forward for further evaluation.

Base perimeter area: Modeling (Appendix G) indicates that addition of a 900 ft long trench to the existing SS042 (CS-2) recovery system will fully capture plume D as well as Plumes F and I. This upgrade is considerably less expensive than the option of constructing a new plume D perimeter collection system (discussed above). For this reason, the upgrade to the upgraded SS042 (CS-2) recovery system is carried forward for further consideration.

Off base area: This plume has not migrated off base and there is no need for off base area remediation.

6.1.4.4 Remediation Options for Plume F

Source area: This plume is diffuse and no localized source area can be identified. Source control, either containment with ex situ treatment or in situ, is not applicable.

Perimeter area: Only monitored natural attenuation and containment with ex situ treatment were evaluated because of the reasons described in the Plume A perimeter area discussion. As indicated in Table 6.3, both the monitored natural attenuation and containment with ex situ treatment options would take 15 to greater than 20 years to meet PRGs. However, containment at the boundary would effectively prevent migration to off base. However, monitored natural attenuation would be less expensive if the plume is no longer expanding (which is difficult to determine with the available data). Because of these reasons, both options will be carried forward.

Off base area: This plume has not migrated off base and there is no need for off base capture and recovery of contaminated groundwater.

6.1.4.5 Remediation Options for Plume H

Source area: This plume is diffuse and no localized source area can be identified in the immediate vicinity of Plume H. Source control in the vicinity of Plume H, either containment with ex situ treatment or in situ, is not feasible.

Perimeter area: For Plume H, only monitored natural attenuation and containment with ex situ treatment were evaluated. Even though the containment with ex situ treatment option meets PRGs in less time than the monitored natural attenuation option (Table 6.4), it is unknown if the additional cost associated with installing and operating the ex situ treatment system outweighs the benefit of the shorter time frame. Because of this, both options are carried forward for further evaluation.

Off base area: This plume has not migrated off base and there is no need for remediation in off base areas.

6.1.4.6 Remediation Options for Plume J

Source area: This plume is diffuse and no localized source area can be identified. Source area control, either containment with ex situ or in situ treatment, is not feasible.

Perimeter area: As shown on Table 6.6, the In Situ Treatment and Containment with Ex Situ Treatment Alternatives would be more effective in meeting PRGs than The Monitored Natural Attenuation Alternative, each meeting PRGs in 5 to 10 years. The Monitored Natural Attenuation Alternative, meeting PRGs in 5 years, is about equally effective. The active remediation systems are more effective in meeting PRGs because there is presently a source term that is continuing to contaminate the groundwater (which is very likely as explained in Appendix G).

Of the active remediation options, the total life cycle cost (capital plus discounted operating costs over the life of the project) of the containment with ex situ treatment is less expensive than the in situ treatment option. Because of this, the containment with ex situ treatment

option will be carried forward. The Monitored Natural Attenuation Alternative will also be carried forward for further evaluation because it represents the least expensive alternative.

Base perimeter:

The contaminant plume would naturally attenuate before reaching the base boundary (Appendix G). Because of this, only monitored natural attenuation was considered for down gradient portions of this plume.

Off base area: This plume has not migrated off base and there is no need for remediation in off base areas.

6.1.4.11 Remediation Options for Plume K

Source area: As shown on Table 6.7, the Monitored Natural Attenuation, In Situ Treatment, and Containment with Ex Situ Treatment Alternatives each would take 5 to 10 years to meet PRGs.

Of the active remediation options, the total life cycle cost of containment with ex situ treatment is less expensive than in situ treatment. Because of this, the Containment with Ex Situ Treatment Alternative will be carried forward for further evaluation. The Monitored Natural Attenuation Alternative will also be carried forward for further evaluation because it represents the least expensive alternative and it meets PRGs in the same time frame as the active remediation alternatives.

Perimeter area: The contamination plume is localized and perimeter control would not be needed because the source area containment captures the entire plume.

Off base area: This plume has not migrated off base and there is no need for remediation in off base areas.

6.2 Alternative Descriptions for Groundwater

The options that survived the screening in Section 6.1.4 are summarized in Table 6.8. Given the nine contaminant plumes and the remediation options presented in Table 6.8, there are more than 8,000 alternatives that could be generated; too many to be evaluated here. The universe of alternatives would include the least and most costly alternatives and the alternatives that would achieve remediation goals in the shortest and longest amount of time. The alternatives presented in this section were developed as reasonable combinations of the feasible options carried forward from the previous section. The alternatives were developed to span a range of cost and remediation time frames. In general, the faster a remedial objective is reached, the more active treatment and costly the alternative would likely be.

Eight GRAs remained following technology screening (Section 5.2.2.3). Seven of the eight (which excludes No Further Action) were used to assemble six new GRAs that are more specific to the multiple contamination plumes in Zone 5 (see Section 5.1.2). These GRAs were developed based on how the remediation system would be implemented and where the response action would be implemented relative to the contamination. The GRAs included the following and are listed across the top of Table 6.9:

- Institutional controls
- Monitored natural attenuation without any form of contaminant plume control
- Containment of the source area through extraction of the groundwater and ex situ treatment of the extracted groundwater
- In situ treatment of the source area and along the perimeter
- Containment of groundwater at the perimeter of the plume (region at which contaminant concentration drops to PRGs or at the base boundary, whichever is closer to the source) through groundwater extraction and ex situ treatment of the extracted groundwater
- Extraction of groundwater in off base regions with treatment of the extracted groundwater in an on base treatment system.

The main components of each option listed in Table 6.8 are discussed in the following subsections. The applicability of each GRA was evaluated for each of the contaminant plumes identified in Section 3.3.2 and Figure 3.10. Table 6.10 indicates combinations of GRAs for specific contaminant plumes (indicated by plume letter) that appeared feasible. In all cases, any contamination that would remain after implementation of the remediation option would be monitored for natural attenuation. The process of determining the applicability of each GRA for each plume is discussed in the following section. Monitored natural attenuation is considered feasible for all plumes and is not discussed below. Alternatives 3 through 7 address all plumes except Plume A. Since a FFS was performed for Plume A, the two alternatives (not including the No Action alternative or monitored natural attenuation) that were carried through the FFS are presented as Alternative 8 and 9 in this report.

6.2.1 Alternative 1 – No Further Action

Consideration of a No Further Action Alternative is required by the NCP to provide a baseline for comparison of the other alternatives. No action would consist of taking no action for the groundwater. It would include existing institutional controls (i.e., controls on the construction and use of shallow aquifer wells in the vicinity of Zone 5) but no new institutional controls. It also would include any natural attenuation of contaminants that occurs without additional human intervention or monitoring.

6.2.2 Alternative 2 – Monitored Natural Attenuation

Alternative 2 considers the use of natural attenuation to remediate the Zone 5 site (Table 6.10). No active remediation of any of the plumes would be conducted. Only monitoring of the progress of natural attenuation would be performed.

6.2.3 Alternative 3 – Source Control

1) This alternative includes:Establishing hydraulic gradients to prevent further migration of contaminant sources
2) Ex-situ treatment of extracted contaminated groundwater

3) Monitored natural attenuation of contaminant plumes that are beyond the zone of influence of the collector trenches or extraction wells used to establish the hydraulic gradients.

Table 6.11 summarizes this alternative and Figure 6.12 shows an overall view of this alternative. Hydraulic barriers would be established to control the flow of groundwater from the source areas for Plumes D and I. Groundwater from Plume I would be extracted with trenches, while Plumes D, and K will be extracted with wells. All the recovery systems would transfer the contaminants to a new GWTP. There is no readily distinguishable source area for Plumes F, H, and J, and contamination in these plumes would be allowed to naturally attenuate without source control.

Contamination that is downgradient from the proposed recovery wells and trenches would be allowed to naturally attenuate. However, any of the Plume D, F, H, and J contaminants that are not naturally attenuated would be captured by existing Zone 1 or Zone 2 recovery systems, and treated at the GWTP.

6.2.4 Alternative 4 – Source Ex Situ and In Situ Treatment, Perimeter Control and Off Base Control

Alternative 4 is similar to Alternative 3 with two exceptions: in situ treatment would be used to eliminate contamination in the source areas of Plume I (rather than using pump and treat); and off base areas of contamination that exceed PRGs would use active remediation (pump and treat), rather than monitored natural attenuation, to reduce contaminant concentrations. Contaminated groundwater extracted from off base locations would be treated in an on base treatment system. Table 6.12 provides a summary of the remediation options for each contaminant plume. Figure 6.13 provides an overall view of Alternative 4 recovery and treatment systems.

Alternative 4 includes establishment of hydraulic barriers to control the flow of groundwater from the source areas of Plumes D; establishment of hydraulic barriers to control the flow of groundwater from the perimeter areas of Plume J. All the new recovery systems would transfer the contaminants to a new GWTP (described in section 6.1.3.3), which would be constructed next to the existing Zone 1, 2, 3 GWTP and EPS systems. Plumes D and F perimeter contamination would be recovered using the Zone 2 recovery system and treated at the GWTP. Monitored natural attenuation was not considered as part of Alternative 4, although it would occur incidental to the active remediation systems being evaluated.

6.2.5 Alternative 5 – Source and Perimeter Control

Alternative 5 is similar in nature to Alternative 3, except it relies solely on monitored natural attenuation as a means of contaminant reduction for Plume K. Table 6.13 provides a summary of the remediation options for each contaminant plume. Figure 6.14 provides an overall view of Alternative 5 recovery and treatment systems.

Alternative 5 includes establishment of hydraulic barriers to control the flow of groundwater from the source areas of Plume D. All the new recovery systems will transfer the contaminants to a new GWTP, which would be constructed next to the existing GWTP. Plumes D, F, and J perimeter contamination would be recovered using Zones 1 and 2

recovery systems and treated at the Zones 1, 2, 3 GWTP. Monitored natural attenuation will reduce contaminant levels in Plume H.

6.2.6 Alternative 6 – Targeted Source and Perimeter Control

Alternative 6 is similar in nature to Alternative 3 except that it does not include source control for Plumes C, D, or K. Plumes D and F would eventually be captured by the existing Zone 2 recovery and treatment system, unless the contaminants naturally attenuate first. Table 6.14 provides a summary of the remediation options for each contaminant plume. Figure 6.15 provides an overall view of Alternative 6 recovery and treatment systems.

There is no readily distinguishable source area for Plumes F, H, and J, and contamination in these plumes would be allowed to naturally attenuate without source control.

Contamination that is downgradient from the proposed recovery wells and trenches would be allowed to naturally attenuate. However, any of the Plume D, F, H, and J contaminants that are not naturally attenuated would be captured by existing Zone 1 or Zone 2 recovery systems, and treated at the Zone 1, 2, 3 GWTP. Any of the Plume I contaminants that are not remediated with monitored natural attenuation would be captured by an upgraded Zone 2 recovery system, and treated at the Zone 1, 2, 3 GWTP.

6.2.7 Alternative 7 – Source Ex Situ and In Situ Treatment and Perimeter Control

Alternative 7 is similar to Alternative 5 except that Alternative 7 uses in situ treatment for control of the Plume D source area. Table 6.15 provides a summary of the options evaluated for each contaminant plume. Figure 6.16 provides an overall view of Alternative 7 recovery and treatment systems.

Alternative 7 includes source control through in situ bioremediation for Plume D. Plumes D, F, H, and J perimeter contamination would be recovered using Zones 1 and 2 recovery systems and treated at the GWTP.

6.2.8 Alternative 8 – In situ Oxygen Treatment of Plume A Source with In situ Perimeter Treatment

Alternative 8 addresses Plume A only and consists of in situ oxygen treatment of the Plume A source and permeable reactive wall at the perimeter.

6.2.9 Alternative 9 – In situ Bioremediation of Plume A Source with In situ Perimeter Treatment

Alternative 9 addresses Plume A only and is similar to Alternative 8 except that instead of in situ oxygen treatment of the Plume A source, anaerobic cometabolic bioremediation of the source will used. A permeable reactive wall would placed at the perimeter.

Table 6.1
Preliminary Design Parameters for Plume A
Kelly AFB, San Antonio, Texas

Remediation Option	Source Area		Perimeter		Off Base	
	Monitored Natural Attenuation	In Situ Treatment	Monitored Natural Attenuation	In Situ Treatment	Monitored Natural Attenuation	In Situ Treatment
Site and Contaminant						
Estimated COC Concentration at Extraction (µg/L)		1,2-DCE: 10 TCE: 100				
Hydraulic Conductivity (ft/day)		200 to 400				
Depth to Navarro (ft)		40				
Depth to Water Table (ft, average)		14 to 33 (27.5)				
Saturated Thickness (ft, average)		0 to 12 (5)				
Recovery System						
Number of Wells[1]		4				
Well Spacing[1] (ft)		160				
Average Well Depth (ft)		40				
Screened Thickness (ft)		12				
Single Well Production Rate (gpm)		5				
Length of Collector Trench(s) (ft)		NA				
Average Trench Depth (ft)		NA				
Trench Production Rate (gpm)		NA				
Recovery System Flow Rate (gpm)		20				
Injection System						
Number of Wells[1]		10				
Well Spacing[1] (ft)		160				
Average Well Depth (ft)		40				
Screened Thickness (ft)		12				
Single Well Injection Rate (gpm)		1				
Treatment						
Treatment Technology	Monitored Natural Attenuation	In situ enhanced biodegradation and ex situ treatment[3]	Monitored Natural Attenuation		Monitored Natural Attenuation	
Treatment System Technology		Cometabolism				
Ex Situ Treatment Capacity[2] (gpm)		40				
In Situ Treatment Capacity[2] (gpm)		20				
Discharge to . . .		Reinjection				
Contaminant Mass Estimate (lb)	29.6	29.6	32.3		38.6	
Time of Operation (years)		5 to >10 (10)[4]				
Time to Achieve PRGs (years)	29	25	26		26	
Capital Cost, $	0	498,000	0		0	
Present Worth Operating Cost, $	159,000	534,000	150,000		159,000	
Total Present Worth Cost, $	159,000	1,032,000	150,000		159,000	
Applicable Figure		6.8				

NA = Not applicable
1 = Number of wells doubled from modeling results to provide a recovery system safety factor of 100 percent. The well spacing and single well production rate were also cut in half to account for this safety factor
2 = Flowrate doubled to provide a 100 percent safety factor for the treatment system.
3 = Injection of 100% of extracted groundwater will cause wide dispersion of the plume beyond the extraction well capture area. After ex situ treatment, injection of 50% of extracted groundwater will facilitate co-metabolism
4 = Design life in parentheses

TABLE 6.2
Preliminary Design Parameters for Plume D
Kelly AFB, San Antonio, Texas

Remediation Option	Source Area			Perimeter			Base Perimeter		
	Monitored Natural Attenuation	In Situ Treatment	Containment	Monitored Natural Attenuation	In Situ Treatment	Containment	Monitored Natural Attenuation	In Situ Treatment	Containment
Site and Contaminant									
Estimated COC Concentration at Extraction (µg/L)		PCE: 18 TCE: 100	PCE: 18 TCE: 100			PCE: 10 TCE: 10			PCE: 10 TCE: 10
Hydraulic Conductivity (ft/day)		21 to 80	21 to 80			21 to 80			21 to 80
Depth to Navarro (ft)		40	40			40			40
Depth to Water Table (ft, average)		18 to 26 (24)	18 to 26 (24)			18 to 26 (24)			18 to 26 (24)
Saturated Thickness (ft, average)		4 to 17 (10)	4 to 17 (10)			4 to 17 (10)			4 to 17 (10)
Recovery System									
Number of Wells[1]		8	8			32			Utilize existing Zone 2 Recovery System with upgrade (see below)
Well Spacing[1] (ft)		140	40 to 80			50 to 150			
Average Well Depth (ft)		40	40			40			
Screened Thickness (ft)		17	17			17			
Single Well Production Rate (gpm)		1 to 8	1.3 to 3.5			1 to 2.5			
Length of Collector Trench(s) (ft)		NA	NA			NA			900
Average Trench Depth (ft)		NA	NA			NA			26 to 30
Trench Production Rate (gpm)		NA	NA			NA			35
Recovery System Flow Rate (gpm)		40	17			35			35
Injection System									
Number of Wells[1]		16							
Well Spacing[1] (ft)		70							
Average Well Depth (ft)		40							
Screened Thickness (ft)		17							
Single Well Injection Rate (gpm)		1 to 1.5							
Treatment									
Treatment Technology		In situ enhanced biodegradation and Ex Situ Treatment[3]	Pump and treat			Pump and treat			Pump and treat
Treatment System Technology		Cometabolism	UV Oxidation			UV Oxidation			Zone 2 upgrades[4]
Ex Situ Treatment Capacity[2] (gpm)		80	34			70			70 (additional flow)
In Situ Treatment Capacity[2] (gpm)		40	NA			NA			NA
Discharge to . . .		Reinjection	EPS to Leon Creek			EPS to Leon Creek			Via EPS to outfall
Contaminant Mass Estimate (lb)	11.9	11.9	11.9	23.0		23.0			23.0
Time of Operation (years)		3 to 45 (16)[5]	23			23			
Time to Achieve PRGs (years)	28	20 to 30	23	28		23			
Capital Cost, $	0	641,000	166,000	0		597,000	0		106,000
Present Worth Operating Cost, $	111,000	638,000	182,000	111,000		1,015,000	111,000		138,000
Total Present Worth Cost, $	111,000	1,279,000	348,000	111,000		1,612,000	111,000		244,000
Applicable Figure		6.15	6.16			6.17			6.18

Not Feasible (Plume perimeter too large for effective implementation of in situ treatment)

NA = Not applicable
1 = Number of wells doubled from modeling results to provide a recovery system safety factor of 100 percent. The well spacing and single well production rate were also cut in half to account for this safety factor
2 = Flowrate doubled to provide a 100 percent safety factor for the treatment system.
3 = Injection of 100% of extracted groundwater will cause wide dispersion of the plume beyond the extraction well capture area. After ex situ treatment, injection of 50% of extracted groundwater will facilitate cometabolism.
4 = Proposed upgrades would capture plumes D, F and I.
5 = Design life in parentheses

TABLE 6.3
Preliminary Design Parameters for Plume F
Kelly AFB, San Antonio, Texas

Remediation Option	Source Area			Perimeter			Off Base		
	Monitored Natural Attenuation	In Situ Treatment	Containment	Monitored Natural Attenuation	In Situ Treatment	Containment	Monitored Natural Attenuation	In Situ Treatment	Containment
Site and Contaminant									
Estimated COC Concentration at Extraction (µg/L)						PCE: 5			
Hydraulic Conductivity (ft/day)						40			
Depth to Navarro (ft)						40			
Depth to Water Table (ft, average)						18 to 26 (24)			
Saturated Thickness (ft, average)						4 to 17 (10)			
Recovery System									
Number of Wells						Utilize existing Zone 2 Recovery System with upgrade			
Well Spacing (ft)						(see below)			
Average Well Depth (ft)						900			
Screened Thickness (ft)						42			
Single Well Production Rate (gpm)						35			
Length of Collector Trench(s) (ft)						35			
Average Trench Depth (ft)									
Trench Production Rate (gpm)									
Recovery System Flow Rate (gpm)	**Plume F is too dispersed to identify a target area for source remediation.**			**Not Feasible (Plume perimeter too large for effective implementation of in situ treatment)**			**No off base component**		
Injection System									
Number of Wells									
Well Spacing (ft)									
Average Well Depth (ft)									
Screened Thickness (ft)									
Single Well Injection Rate (gpm)									
Treatment									
Treatment Technology						Pump and treat			
Treatment System Technology						Zone 2 upgrades[2]			
Ex Situ Treatment Capacity[1] (gpm)						70 (additional flow)			
In Situ Treatment Capacity[1] (gpm)						NA			
Discharge to . . .						Via EPS to outfall			
Contaminant Mass Estimate (lb)				8.0		8.0			
Time of Operation (years)						15 to >20 (20)[3]			
Time to Achieve PRGs (years)				15 to >20		15 to >20			
Capital Cost, $				0		106,000			
Present Worth Operating Cost, $				207,000		226,000			
Total Present Worth Cost, $				207,000		332,000			
Applicable Figure						6.18			

NA = Not applicable
1 = Flowrate doubled to provide a 100 percent safety factor for the treatment system.
2 = Proposed upgrades would capture plumes D, F and I.
3 = Design life in parentheses.

TABLE 6.4
Preliminary Design Parameters for Plume H
Kelly AFB, San Antonio, Texas

Remediation Option	Source Area: Monitored Natural Attenuation	Source Area: In Situ Treatment	Source Area: Containment	Perimeter: Monitored Natural Attenuation	Perimeter: In Situ Treatment	Perimeter: Containment	Off Base: Monitored Natural Attenuation	Off Base: In Situ Treatment	Off Base: Containment
Site and Contaminant									
Estimated COC Concentration at Extraction (µg/L)						1,2-DCE: 4 TCE: 5			
Hydraulic Conductivity (ft/day)						50 to 80			
Depth to Navarro (ft)						25			
Depth to Water Table (ft, average)						12 to 26 (21)			
Saturated Thickness (ft, average)						0 to 16 (6)			
Recovery System									
Number of Wells[1]						16			
Well Spacing[1] (ft)						85			
Average Well Depth (ft)						25			
Screened Thickness (ft)						16			
Single Well Production Rate (gpm)						5			
Length of Collector Trench(s) (ft)						NA			
Average Trench Depth (ft)						NA			
Trench Production Rate (gpm)						NA			
Recovery System Flow Rate (gpm)						80			
Injection System									
Number of Wells									
Well Spacing (ft)									
Average Well Depth (ft)									
Screened Thickness (ft)									
Single Well Injection Rate (gpm)									
Treatment									
Treatment Technology						Pump and treat			
Treatment System Technology						UV oxidation			
Ex Situ Treatment Capacity[2] (gpm)						160			
In Situ Treatment Capacity[2] (gpm)						NA			
Discharge to . . .						Via EPS to outfall			
Contaminant Mass Estimate (lb)				4.1		4.1			
Time of Operation (years)						6			
Time to Achieve PRGs (years)				7		6			
Capital Cost, $				0		243,000			
Present Worth Operating Cost, $				119,000		169,000			
Total Present Worth Cost, $				119,000		412,000			
Applicable Figure						6.19			

Plume H is too dispersed to identify a target area for source remediation.

Not Feasible (Plume perimeter too large for effective implementation of in situ treatment)

No off base component

NA = Not applicable
1 = Number of wells doubled from modeling results to provide a recovery system safety factor of 100 percent. The well spacing and single well production were also cut in half to account for this safety factor
2 = Flowrate doubled to provide a 100 percent safety factor for the treatment system.

Table 6.5
Preliminary Design Parameters for Plume I
Kelly AFB, San Antonio, Texas

Remediation Option	Source Area			Perimeter			Off Base		
	Monitored Natural Attenuation	In Situ Treatment	Containment	Monitored Natural Attenuation	In Situ Treatment	Containment	Monitored Natural Attenuation	In Situ Treatment	Containment
Site and Contaminant									
Estimated COC Concentration at Extraction (µg/L)		1,2-DCE: 71 PCE: 100 TCE: 15	1,2-DCE: 71 PCE: 100 TCE: 15			1,2-DCE: 10 PCE: 100 TCE: 10			
Hydraulic Conductivity (ft/day)		50 to 80	50 to 80			50 to 80			
Depth to Navarro (ft)		40	40			40			
Depth to Water Table (ft, average)		12 to 26 (21)	12 to 26 (21)			12 to 26 (21)			
Saturated Thickness (ft, average)		0 to 16 (6)	0 to 16 (6)			0 to 16 (6)			
Recovery System									
Number of Wells[1]		NA	NA			Utilize existing Zone 2 Recovery System with upgrade (see below)			
Well Spacing[1] (ft)		NA	NA						
Average Well Depth (ft)		NA	NA						
Screened Thickness (ft)		NA	NA						
Single Well Production Rate (gpm)		NA	NA						
Length of Collector Trench(s) (ft)		750	750			900			
Average Trench Depth (ft)		42	42			42			
Trench Production Rate (gpm)		26	20			35			
Recovery System Flow Rate (gpm)		26	20			35			
Injection System									
Number of Wells[1]		10							
Well Spacing[1] (ft)		60 to 200							
Average Well Depth (ft)		40							
Screened Thickness (ft)		16							
Single Well Injection Rate (gpm)		1							
Treatment									
Treatment Technology		In situ enhanced biodegradation and ex situ treatment[3]	Pump and treat			Pump and treat			
Treatment System Technology		Cometabolism	UV oxidation			Zone 2 upgrades[4]			
Ex Situ Treatment Capacity[2] (gpm)		52	40			70 (additional flow)			
In Situ Treatment Capacity[2] (gpm)		26	NA			NA			
Discharge to . . .		Reinjection	Via EPS to outfall			Via EPS to outfall			
Contaminant Mass Estimate (lb)	46.0	46.0	46.0	275		275			
Time of Operation, years		3 to 45 (22)[5]	22			25 to >30 (30)[5]			
Time to Achieve PRGs, years	25 to >30	25 to >30	25 to >30	25 to >30		25 to >30			
Capital Cost, $	0	740,000	269,000	0		106,000			
Present Worth Operating Cost, $	159,000	785,000	218,000	159,000		181,000			
Total Present Worth Cost, $	159,000	1,525,000	487,000	159,000		287,000			
Applicable Figure		6.20	6.21			6.18			

Not Feasible
(Plume perimeter too large for effective implementation of in situ treatment)

No off base component

NA = Not applicable
1 = Number of wells doubled from modeling results to provide a recovery system safety factor of 100 percent. The well spacing and single well production were also cut in half to account for this safety factor
2 = Flowrate doubled to provide a 100 percent safety factor for the treatment system.
3 = Injection of 100% of extracted groundwater will cause wide dispersion of the plume beyond the extraction well capture area. After ex situ treatment, injection of 40% of extracted groundwater will facilitate cometabolism.
4 = Proposed upgrades would capture plumes D, F and I.
5 = Design life in parentheses

Table 6.6
Preliminary Design Parameters for Plume J
Kelly AFB, San Antonio, Texas

Remediation Option	Source Area: Monitored Natural Attenuation	Source Area: In Situ Treatment	Source Area: Containment	Perimeter: Monitored Natural Attenuation	Perimeter: In Situ Treatment	Perimeter: Containment	Base Perimeter: Monitored Natural Attenuation	Base Perimeter: In Situ Treatment	Base Perimeter: Containment
Site and Contaminant									
Estimated COC Concentration at Extraction (µg/L)					PCE: 5 TCE: 5	PCE: 5 TCE: 5			
Hydraulic Conductivity (ft/day)					4 to 77	4 to 77			
Depth to Navarro (ft)					40	40			
Depth to Water Table (ft, average)					8 to 34 (26)	8 to 34 (26)			
Saturated Thickness (ft, average)					2 to 10 (4)	2 to 10 (4)			
Recovery System									
Number of Wells[1]					26	26			
Well Spacing[1] (ft)					90	90			
Average Well Depth (ft)					40	40			
Screened Thickness (ft)					4	4			
Single Well Production Rate (gpm)					0.5 to 2.5	0.5 to 2.5			
Length of Collector Trench(s) (ft)					NA	NA			
Average Trench Depth (ft)					NA	NA			
Trench Production Rate (gpm)					NA	NA			
Recovery System Flow Rate (gpm)					50	50			
Injection System	**Plume J is too dispersed to identify a target area for source remediation.**						**Plume naturally attenuates prior to reaching base perimeter.**		
Number of Wells[1]					20				
Well Spacing[1] (ft)					117				
Average Well Depth (ft)					40				
Screened Thickness (ft)					10				
Single Well Injection Rate (gpm)					1.5				
Treatment									
Treatment Technology					In situ enhanced biodegradation and ex situ treatment[3]	Pump and treat			
Treatment System Technology					Cometabolism	UV oxidation			
Ex Situ Treatment Capacity[2] (gpm)					100	100			
In Situ Treatment Capacity[2] (gpm)					50	NA			
Discharge to . . .					Reinjection	Via EPS to outfall			
Contaminant Mass Estimate (lb)				2.5	2.5	2.5	2.5		
Time of Operation, years					5 to 10 (10)[4]	5			
Time to Achieve PRGs, years				7	5 to 10	5	5		
Capital Cost, $				0	1,150,000	443,000	0		
Present Worth Operating Cost, $				111,000	534,000	175,000	111,000		
Total Present Worth Cost, $				111,000	1,684,000	618,000	111,000		
Applicable Figure					6.22	6.23			

NA = Not applicable
1 = Number of wells doubled from modeling results to provide a recovery system safety factor of 100 percent. The well spacing and single well production were also cut in half to account for this safety factor
2 = Flowrate doubled to provide a 100 percent safety factor for the treatment system
3 = Injection of 100% of extracted groundwater will cause wide dispersion of the plume beyond the extraction well capture area. After ex situ treatment, injection of 50% of extracted groundwater will facilitate co-metabolism
4 = Design life in parentheses

Table 6.7
Preliminary Design Parameters for Plume K
Kelly AFB, San Antonio, Texas

Remediation Option	Source Area			Perimeter			Off Base		
	Monitored Natural Attenuation	In Situ Treatment	Containment	Monitored Natural Attenuation	In Situ Treatment	Containment	Monitored Natural Attenuation	In Situ Treatment	Containment
Site and Contaminant									
Estimated COC Concentration at Extraction (µg/L)		CB: 100	CB. 100						
Hydraulic Conductivity (ft/day)		4 to 77	4 to 77						
Depth to Navarro (ft)		40	40						
Depth to Water Table (ft, average)		8 to 34 (26)	8 to 34 (26)						
Saturated Thickness (ft, average)		2 to 10 (4)	2 to 10 (4)						
Recovery System									
Number of Wells		6	2						
Well Spacing (ft)		50	100						
Average Well Depth (ft)		40	40						
Screened Thickness (ft)		10	10						
Single Well Production Rate (gpm)		1 to 8	7						
Length of Collector Trench(s) (ft)		800	NA						
Average Trench Depth (ft)		42	NA						
Trench Production Rate (gpm)		30	NA						
Recovery System Flow Rate (gpm)		40	14						
Injection System									
Number of Wells		16							
Well Spacing (ft)		50							
Average Well Depth (ft)		40							
Screened Thickness (ft)		10							
Single Well Injection Rate (gpm)		1 to 1.2							
Treatment									
Treatment Technology		In situ enhanced biodegradation and ex situ treatment[3]	Pump and treat						
Treatment System Technology		Cometabolism	UV Oxidation						
Ex Situ Treatment Capacity[2] (gpm)		80	30						
In Situ Treatment Capacity[2] (gpm)		40	NA						
Discharge to . . .		Reinjection	EPS to Leon Creek						
Contaminant Mass Estimate (lb)	5.5	5.5	5.5						
Time of Operation, years		5 TO 10 (10)[4]	5 to 10 (10)[4]						
Time to Achieve PRGs, years	5 to 10	5 to 10	5 to 10						
Capital Cost, $	0	626,000	52,000						
Present Worth Operating Cost, $	93,000	484,000	122,000						
Total Present Worth Cost, $	93,000	1,110,000	174,000						
Applicable Figure		6.24	6.25						
				Due to the limited dispersion of Plume K, perimeter and source control are considered an equivalent approach.			**No off base component**		

NA = Not applicable
1 = Number of wells doubled from modeling results to provide a recovery system safety factor of 100 percent. The well spacing and single well production rate were also cut in half to account for this safety factor
2 = Flowrate doubled to provide a 100 percent safety factor for the treatment system.
3 = Injection of 100% of extracted groundwater will cause wide dispersion of the plume beyond the extraction well capture area. After ex situ treatment, injection of 50% of extracted groundwater will facilitate co-metabolism.
4 = Design life in parentheses.

TABLE 6.8
General Response Actions Available for Each Contaminant Plume
Kelly AFB, San Antonio, Texas

	Groundwater Plume Designation										
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
General Response Action	On and Off Base TCE, 1,2-DCE	Off Base PCE	Chlorobenzene, Arsenic	1600 Area TCE/PCE, 1,2-DCE	Civil Engineering Motor Pool Benzene	Low Concentration PCE/TCE	SS045 (S-10) and ST007 (S-5) Benzene Spill, Arsenic	Central Runway TCE	PCE/TCE/DCE	1100 Area PCE, TCE	West Chlorobenzene
Monitored Natural Attenuation	**Treatment:** Natural attenuation	Not addressed by this CMS	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	To be closed under Separate Compliance Plan	**Treatment:** Natural attenuation	To be closed under Separate Compliance Plan	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation
Source Area Containment and Ex Situ Treatment	NA		NA	**Extraction:** Wells/trenches at 100 ppb **Treatment:** UV oxidation		NA		NA	**Extraction:** Wells/trenches at 100 ppb (focused around Hangar 375) **Treatment:** UV oxidation	NA	**Extraction:** Wells at high concentration locations **Treatment:** UV oxidation
Source Area In Situ Treatment	**Injection:** Injection wells **Treatment:** Enhanced biological degradation or In situ Oxygen Treatment		NA	**Injection:** Injection wells **Treatment:** Enhanced biological degradation		NA		NA	**Injection:** Injection wells **Treatment:** Enhanced biological degradation	NA	NA
Perimeter Area Containment and Ex Situ Treatment	NA		NA	**Extraction and Treatment:** Zone 2 (SS042 [CS-2]) upgrades		**Extraction and Treatment:** Zone 2 (SS042 [CS-2]) upgrades		**Extraction:** Wells at MCL concentrations **Treatment:** UV oxidation	**Extraction and Treatment:** Zone 2 (SS042 [CS-2], ITWP, WP022 [E-3]) upgrades	**Extraction:** Wells at MCL concentrations **Treatment:** UV oxidation	NA
Perimeter Area In Situ Treatment	**Treatment: Flow through Reactive Walls**		NA	NA		NA		NA	NA	NA	NA
Off Base Extraction and Treatment	NA		NA	NA		NA		NA	NA	NA	NA

NA = Indicated treatment is not applicable for plume.

TABLE 6.9
General Response Actions Appropriate for Each Contaminant Plume
Kelly AFB, San Antonio, Texas

Alternative Number[1]	Institutional Controls	Natural Attenuation	Monitoring	Source Ex Situ Treatment	Source In Situ Treatment	Perimeter Collection and Treatment	Perimeter In Situ Treamtment	Off Base Collection and Treatment
1	Only those currently existing	All plumes	No					
2	Yes	All plumes, except A	Yes					
3	Yes	All plumes, except A	Yes	D, I, K		D, F, H, I, J		
4	Yes	Plume K	Yes	D	I	D, F, H, I, J		
5	Yes	All plumes, except A	Yes	D, I		D, F, H, I, J		
6	Yes	All plumes, except A	Yes	I		D, F, H, I, J		
7	Yes	All plumes, except A	Yes	I	D	D, F, H, I, J		
8	Yes	A	Yes		A		A	
9	Yes	A	Yes		A		A	

[1]Alternative Numbers:

1 – No Further Action
2 – Monitored Natural Attenuation
3 – Source Control
4 – Source Ex Situ and In Situ Treatment, Perimeter Control and Off Base Control
5 – Source and Perimeter Control
6 – Targeted Source and Perimeter Control
7 – Source Ex Situ and In Situ Treatment and Perimeter Control
8 – Source In Situ Oxygen Treatment and Reactive Wall at Perimeter (Plume A only)
9 – Source In Situ Enhanced Biodegradation and Reactive Wall at Perimeter (Plume A only)

TABLE 6.10
Alternative 2 - Monitored Natural Attenuation
Kelly AFB, San Antonio, Texas

	Groundwater Plume Designation									
	B	C	D	E	F	G	H	I	J	K
General Response Action	Off Base PCE	Chlorobenzene, Arsenic	1600 Area TCE/PCE, 1,2-DCE	Civil Engineering Motor Pool Benzene	Low Concentration PCE/TCE	SS045 (S-10) and ST007 (S-5) Benzene Spill, Arsenic	Central Runway TCE	PCE/TCE/DCE	1100 Area PCE, TCE	West Chlorobenzene
Monitored Natural Attenuation	Not addressed by this CMS	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	To be closed under Separate Compliance Plan	**Treatment:** Natural attenuation	To be closed under Separate Compliance Plan	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation
Source Area Containment and Ex Situ Treatment		None	None		NA		NA	None	NA	None
Source Area In Situ Treatment		NA	None		NA		NA	NA	NA	None
Perimeter Area Containment and Ex Situ Treatment		NA	None		None		None	None	None	NA
Off Base Extraction and Treatment		NA	NA		NA		NA	NA	NA	NA

NA = Indicated treatment is not applicable for plume.
None = General response action not part of this alternative.

TABLE 6.11
Alternative 3 - Source Control
Kelly AFB, San Antonio, Texas

	Groundwater Plume Designation									
	B	C	D	E	F	G	H	I	J	K
General Response Action	Off Base PCE	Chlorobenzene, Arsenic	1600 Area TCE/PCE, 1,2-DCE	Civil Engineering Motor Pool Benzene	Low Concentration PCE/TCE	SS045 (S-10) and ST007 (S-5) Benzene Spill, Arsenic	Central Runway TCE	PCE/TCE/DCE	1100 Area PCE, TCE	West Chlorobenzene
Monitored Natural Attenuation	Not addressed by this CMS	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	To be closed under Separate Compliance Plan	**Treatment:** Natural attenuation	To be closed under Separate Compliance Plan	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation
Source Area Containment and Ex Situ Treatment		None	**Extraction:** Wells/trenches at 100 ppb **Treatment:** UV oxidation		NA		NA	**Extraction:** Wells/trenches at 100 ppb (focused around Hangar 375) **Treatment:** UV oxidation	NA	**Extraction:** Wells at high concentration locations **Treatment:** UV oxidation
Source Area In Situ Treatment		NA	None		NA		NA	NA	NA	**None**
Perimeter Area Containment and Ex Situ Treatment		NA	**Extraction and Treatment:** Zone 2 (SS042 [CS-2]) upgrades		**Extraction and Treatment:** Zone 2 (SS042 [CS-2]) upgrades		**Extraction and Treatment:** Existing Zone 1 (D4/D5) system	**Extraction and Treatment:** Zone 2 (SS042 [CS-2]) upgrades	**Extraction and Treatment:** Existing Zone 1 (D2) system	NA
Off Base Extraction and Treatment		NA	NA		NA		NA	NA	NA	NA

NA = Indicated treatment is not applicable for plume.
None = General response action not part of this alternative.
X = Indicated response is potentially applicable for the indicated groundwater contamination plume.

TABLE 6.12
Alternative 4 - Source Ex Situ and In Situ Treatment, Perimeter, and Off Base Control
Kelly AFB, San Antonio, Texas

	Groundwater Plume Designation									
	B	C	D	E	F	G	H	I	J	K
General Response Action	Off Base PCE	Chlorobenzene, Arsenic	1600 Area TCE/PCE, 1,2-DCE	Civil Engineering Motor Pool Benzene	Low Concentration PCE/TCE	SS045 (S-10) and ST007 (S-5) Benzene Spill, Arsenic	Central Runway TCE	PCE/TCE/DCE	1100 Area PCE, TCE	West Chlorobenzene
Monitored Natural Attenuation	Not addressed by this CMS	None	None	To be closed under Separate Compliance Plan	None	To be closed under Separate Compliance Plan	None	None	None	None
Source Area Containment and Ex Situ Treatment		**Extraction and Treatment:** None	**Extraction:** Wells/trenches at 100 ppb **Treatment:** UV oxidation		NA		NA	None	NA	None
Source Area In Situ Treatment		NA	NA		NA		NA	NA		None
Perimeter Area Containment and Ex Situ Treatment		NA	**Extraction and Treatment:** Zone 2 (SS042 [CS-2]) upgrades		**Extraction and Treatment:** Zone 2 (SS042 [CS-2]) upgrades		**Extraction:** Wells at MCL concentrations **Treatment:** UV oxidation	**Extraction and Treatment:** Zone 2 (SS042 [CS-2]) upgrades	**Extraction:** Wells at MCL concentrations **Treatment:** UV oxidation	NA
Off Base Extraction and Treatment		NA	NA		NA		NA	NA	NA	NA

NA = Indicated treatment is not applicable for plume.
None = General response action not part of this alternative.

TABLE 6.13
Alternative 5 - Source and Perimeter Control
Kelly AFB, San Antonio, Texas

	Groundwater Plume Designation									
	B	C	D	E	F	G	H	I	J	K
General Response Action	Off Base PCE	Chlorobenzene, Arsenic	1600 Area TCE/PCE, 1,2-DCE	Civil Engineering Motor Pool Benzene	Low Concentration PCE/TCE	SS045 (S-10) and ST007 (S-5) Benzene Spill, Arsenic	Central Runway TCE	PCE/TCE/DCE	1100 Area PCE, TCE	West Chlorobenzene
Monitored Natural Attenuation	Not addressed by this CMS	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	To be closed under Separate Compliance Plan	**Treatment:** Natural attenuation	To be closed under Separate Compliance Plan	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation
Source Area Containment and Ex Situ Treatment		None	**Extraction:** Wells/trenches at 100 ppb **Treatment:** UV oxidation		NA		NA	**Extraction:** Wells/trenches at 100 ppb (focused around Hangar 375) **Treatment:** UV oxidation	NA	None
Source Area In Situ Treatment		NA	None		NA		NA	NA	NA	None
Perimeter Area Containment and Ex Situ Treatment		NA	**Extraction and Treatment:** Zone 2 (SS042 [CS-2]) upgrades		**Extraction and Treatment:** Zone 2 (SS042 [CS-2]) upgrades		**Extraction and Treatment:** Existing Zone 1 (D4/D5) system	**Extraction and Treatment:** Zone 2 (SS042 [CS-2]) upgrades	**Extraction and Treatment:** Existing Zone 1 (D2) system	NA
Off Base Extraction and Treatment		NA	NA		NA		NA	NA	NA	NA

NA = Indicated treatment is not applicable for plume.
None = General response action not part of this alternative.

TABLE 6.14
Alternative 6 – Targeted Source and Perimeter Control
Kelly AFB, San Antonio, Texas

	Groundwater Plume Designation									
	B	C	D	E	F	G	H	I	J	K
General Response Action	Off Base PCE	Chlorobenzene, Arsenic	1600 Area TCE/PCE, 1,2-DCE	Civil Engineering Motor Pool Benzene	Low Concentration PCE/TCE	SS045 (S-10) and ST007 (S-5) Benzene Spill, Arsenic	Central Runway TCE	PCE/TCE/DCE	1100 Area PCE, TCE	West Chlorobenzene
Monitored Natural Attenuation	Not addressed by this CMS	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	To be closed under Separate Compliance Plan	**Treatment:** Natural attenuation	To be closed under Separate Compliance Plan	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation
Source Area Containment and Ex Situ Treatment		None	None		NA		NA	**Extraction:** Wells/trenches at 100 ppb (focused around Hangar 375) **Treatment:** UV oxidation	NA	None
Source Area In Situ Treatment		NA	None		NA		NA	NA	NA	None
Perimeter Area Containment and Ex Situ Treatment		NA	**Extraction and Treatment:** Zone 2 (SS042 [CS-2], ITWP, WP022 [E-3]) upgrades		**Extraction and Treatment:** Zone 2 (SS042 [CS-2], ITWP, WP022 [E-3]) upgrades		**Extraction and Treatment:** Existing Zone 1 (D4/D5) system	**Extraction and Treatment:** Zone 2 (SS042 [CS-2], ITWP, WP022 [E-3]) upgrades	**Extraction and Treatment:** Existing Zone 1 (D2) system	NA
Off Base Extraction and Treatment		NA	NA		NA		NA	NA	NA	NA

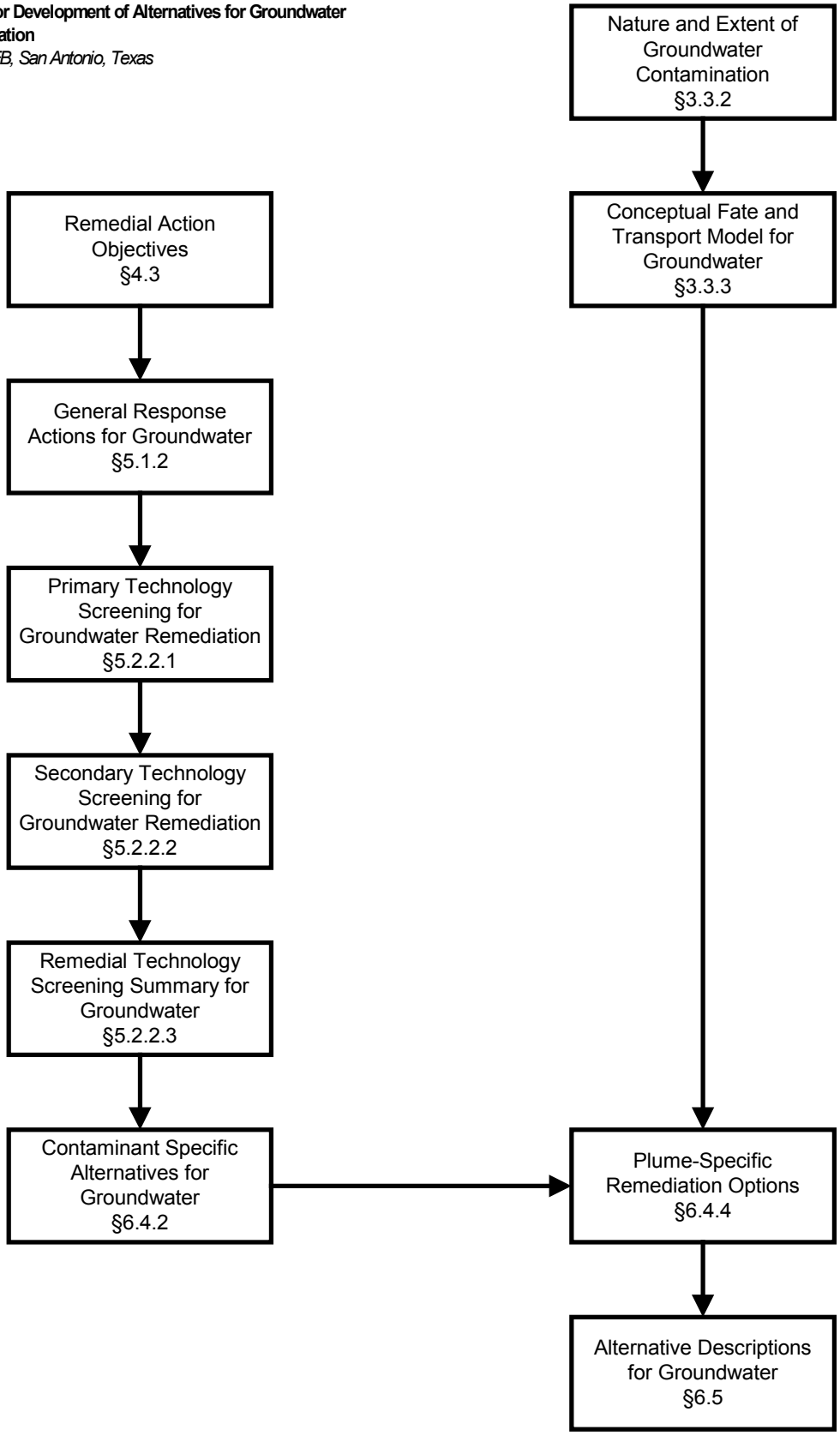
NA = Indicated treatment is not applicable for plume.
None = General response action not part of this alternative..

TABLE 6.15
Alternative 7 – Source Ex Situ and In Situ Treatment, Perimeter Control
Kelly AFB, San Antonio, Texas

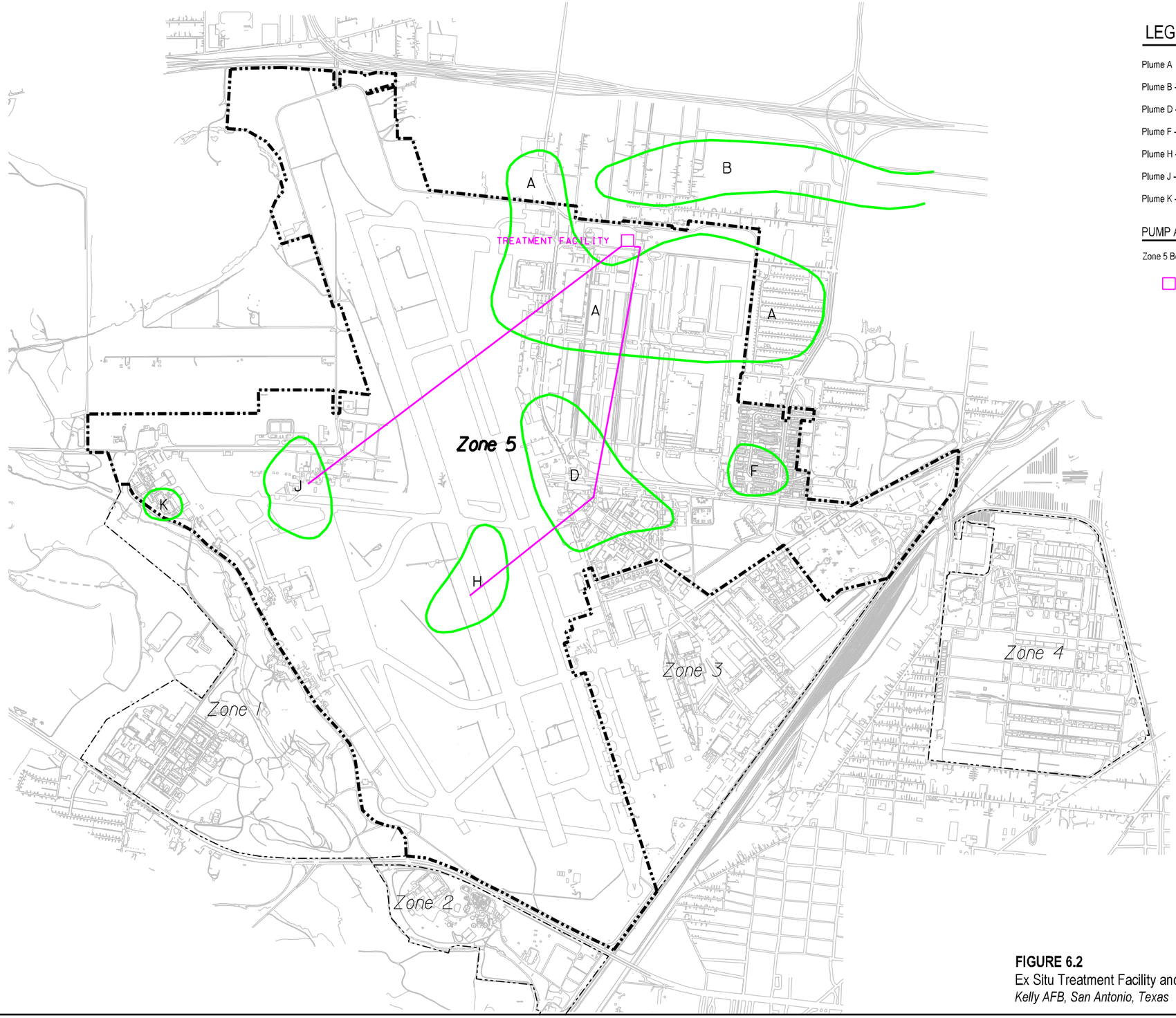
	Groundwater Plume Designation									
	B	C	D	E	F	G	H	I	J	K
General Response Action	Off Base PCE	Chlorobenzene, Arsenic	1600 Area TCE/PCE, 1,2-DCE	Civil Engineering Motor Pool Benzene	Low Concentration PCE/TCE	SS045 (S-10) and ST007 (S-5) Benzene Spill, Arsenic	Central Runway TCE	PCE/TCE/DCE	1100 Area PCE, TCE	West Chlorobenzene
Monitored Natural Attenuation	Not addressed by this CMS	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	To be closed under Separate Compliance Plan	**Treatment:** Natural attenuation	To be closed under Separate Compliance Plan	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation	**Treatment:** Natural attenuation
Source Area Containment and Ex Situ Treatment		None	None		NA		NA	**Extraction:** Wells/trenches at 100 ppb (focused around Hangar 375) **Treatment:** UV oxidation	NA	None
Source Area In Situ Treatment		NA	**Injection:** Nutrient solution **Treatment:** Enhanced biological degradation		NA		NA	NA	NA	None
Perimeter Area Containment and Ex Situ Treatment		NA	**Extraction and Treatment:** Zone 2 (SS042 [CS-2]), upgrades		**Extraction and Treatment:** Zone 2 (SS042 [CS-2]), upgrades		**Extraction and Treatment:** Existing Zone 1 (D4/D5) system	**Extraction and Treatment:** Zone 2 (SS042 [CS-2]) upgrades	**Extraction and Treatment:** Existing Zone 1 (D2) system	NA
Off Base Extraction and Treatment		NA	NA		NA		NA	NA	NA	NA

NA = Indicated treatment is not applicable for plume.
None = General response action not part of this alternative.

FIGURE 6.1
Logic for Development of Alternatives for Groundwater Remediation
Kelly AFB, San Antonio, Texas



1



LEGEND

Plume A - On and Offbase TCE

Plume B - Offbase PCE

Plume D - SS045 (S-10) and 1600 Area TCE, PCE, 1,2-DCE

Plume F - Low Concentration PCE/TCE

Plume H - Central Runway TCE

Plume J - KY028 (1100 Area) PCE, TCE

Plume K - West Chlorobenzene

PUMP AND TREAT

Zone 5 Boundary

Proposed Treatment Facility

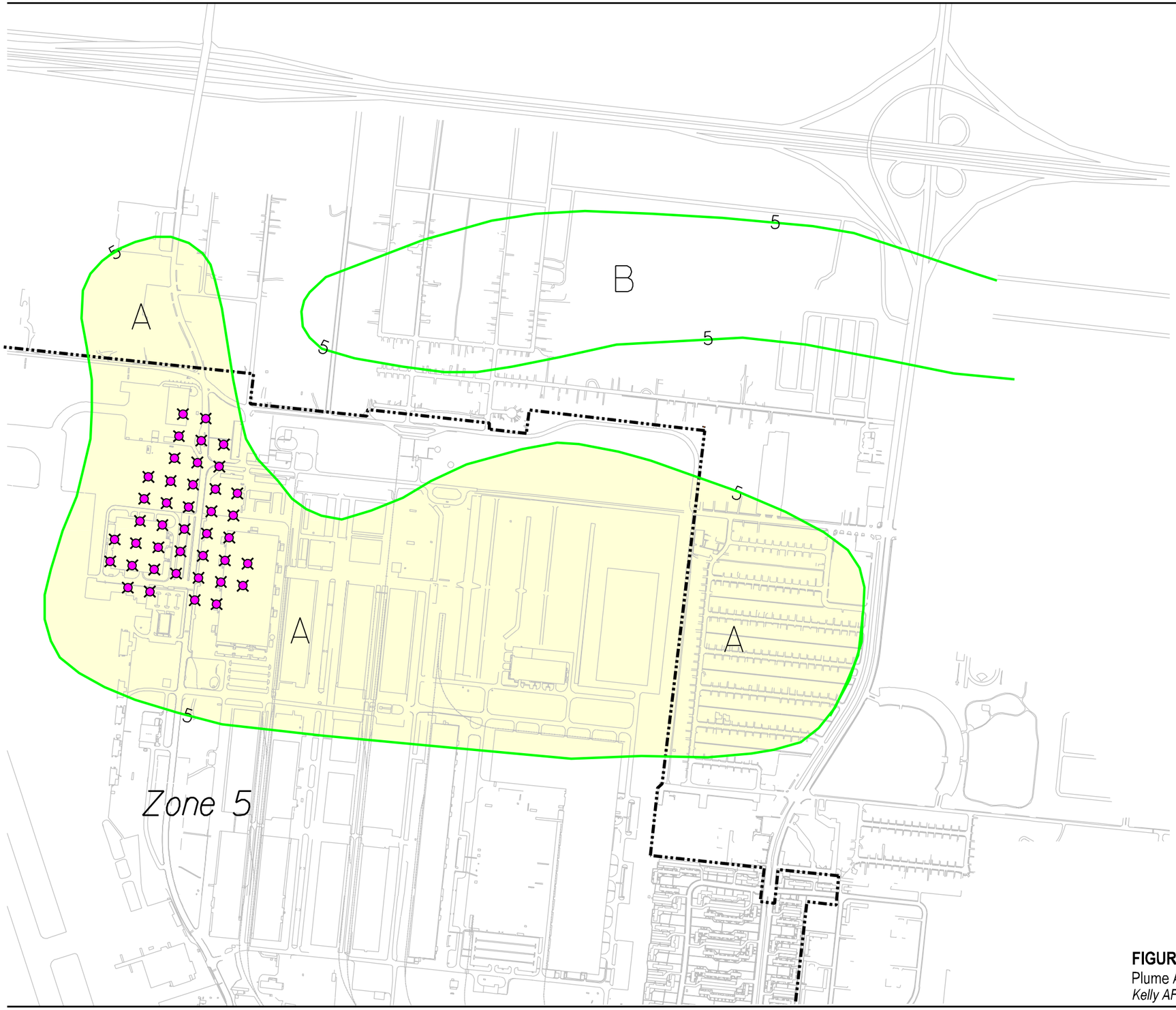
N

0 1000' 2000' 3000'

AIR FORCE BASE CONVERSION AGENCY

FIGURE 6.2
Ex Situ Treatment Facility and Influent Header
Kelly AFB, San Antonio, Texas

CH2MHILL



LEGEND

Plume

Zone 5 Boundary

In Situ Treatment

Injection Well

Notes:

1. Location of all equipment and systems are approximate for this conceptual design.
2. All equipment and systems shown on this diagram are proposed and do not currently exist at the site.
3. See Figure 6.2 for location within Zone 5.
4. Shaded portions of figure are plumes that are targeted for treatment.

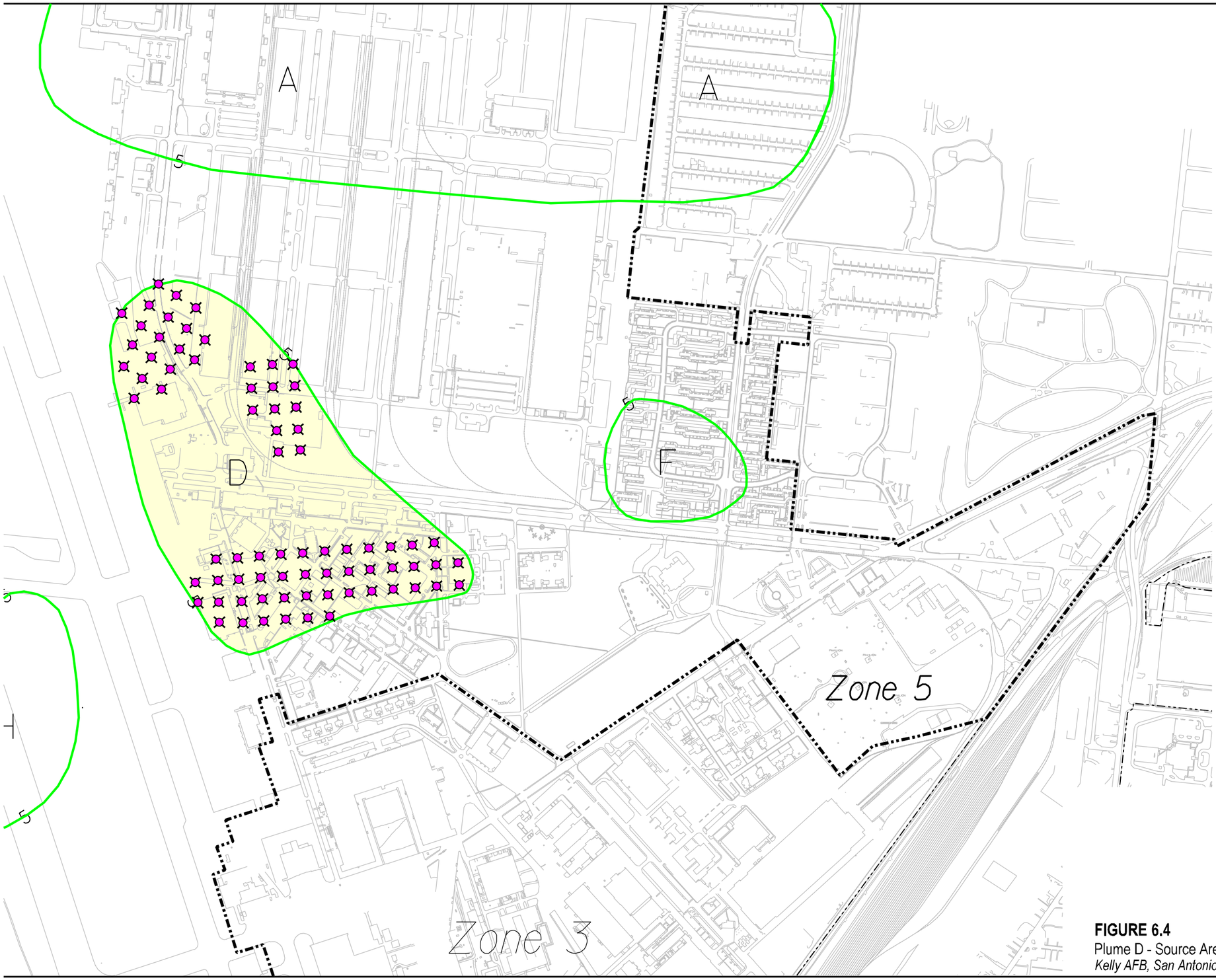
N

0 400' 800' 1200'

AIRFORCE BASE CONVERSION AGENCY

FIGURE 6.3
Plume A - Source Area In Situ Treatment
Kelly AFB, San Antonio, Texas

CH2MHILL



LEGEND

Plume

Zone 5 Boundary

In Situ Treatment

Injection Well

Notes:

1. Location of all equipment and systems are approximate for this conceptual design.
2. All equipment and systems shown on this diagram are proposed and do not currently exist at the site.
3. See Figure 6.2 for location within Zone 5.
4. Shaded portions of figure are plumes that are targeted for treatment.

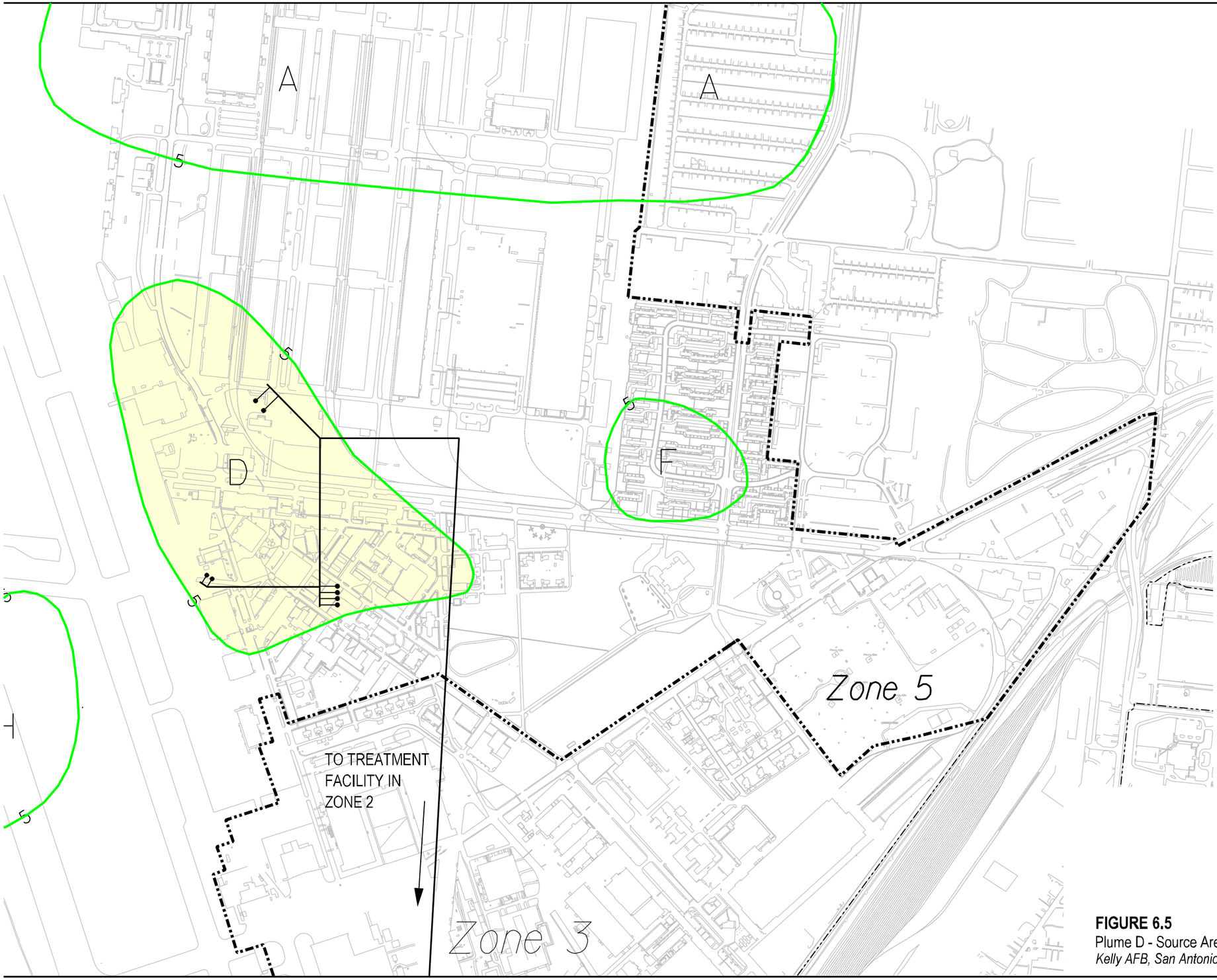
N

0 400' 800' 1200'

AIRFORCE BASE CONVERSION AGENCY

FIGURE 6.4
Plume D - Source Area In Situ Treatment
Kelly AFB, San Antonio, Texas

CH2MHILL



LEGEND

Plume

Zone 5 Boundary

Pump and Treat

Extraction Well (8)

Transfer Piping

Notes:

1. Location of all equipment and systems are approximate for this conceptual design.
2. All equipment and systems shown on this diagram are proposed and do not currently exist at the site.
3. See Figure 6.2 for location within Zone 5.
4. Shaded portions of figure are plumes that are targeted for treatment.

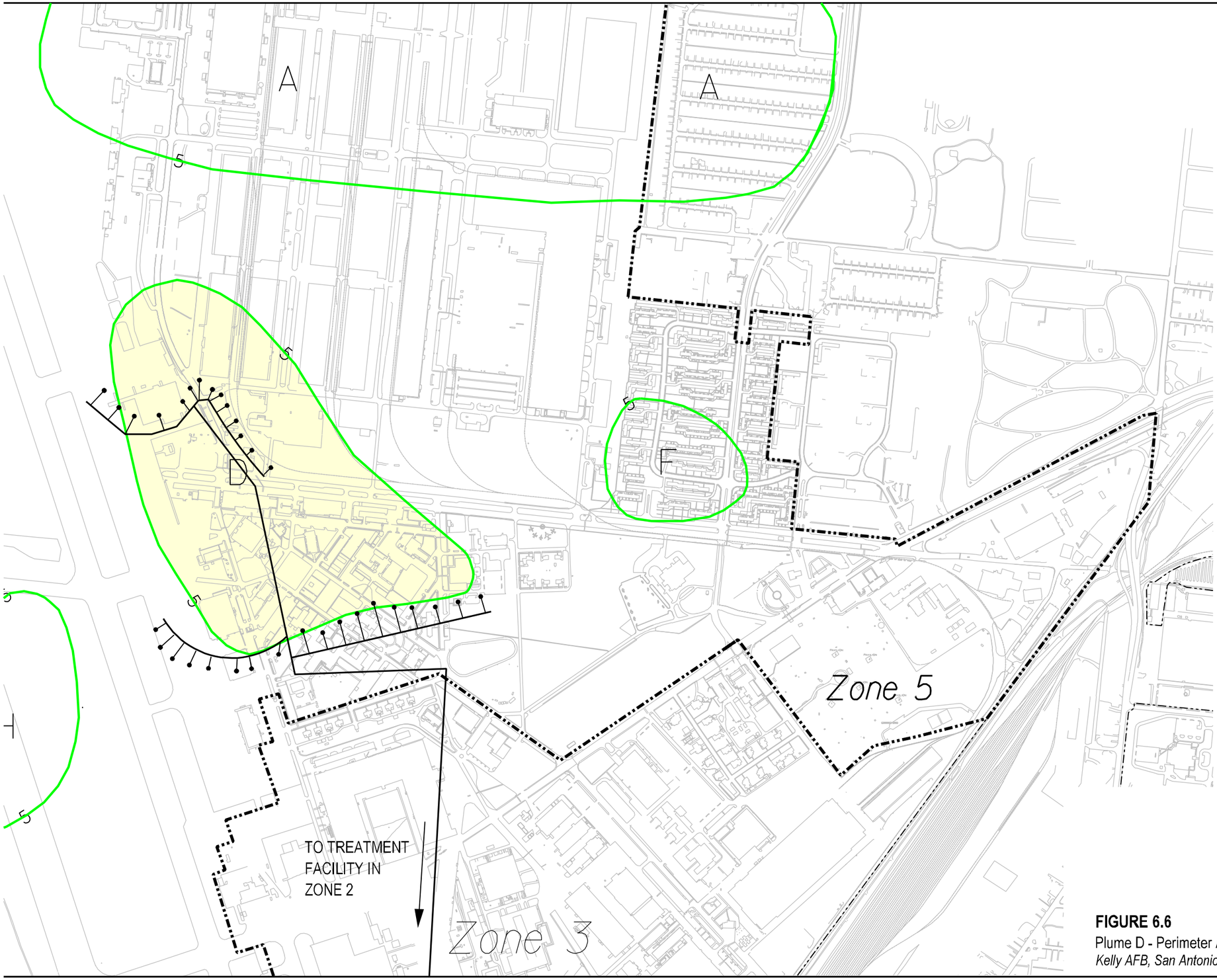
N

0 400' 800' 1200'

AIRFORCE BASE CONVERSION AGENCY

FIGURE 6.5
Plume D - Source Area Containment and Ex Situ Treatment
Kelly AFB, San Antonio, Texas

CH2MHILL



LEGEND

Plume

Zone 5 Boundary

Pump and Treat

Extraction Well (32)

Transfer Piping

Notes:

1. Location of all equipment and systems are approximate for this conceptual design.
2. All equipment and systems shown on this diagram are proposed and do not currently exist at the site.
3. See Figure 6.2 for location within Zone 5.
4. Shaded portions of figure are plumes that are targeted for treatment.

N

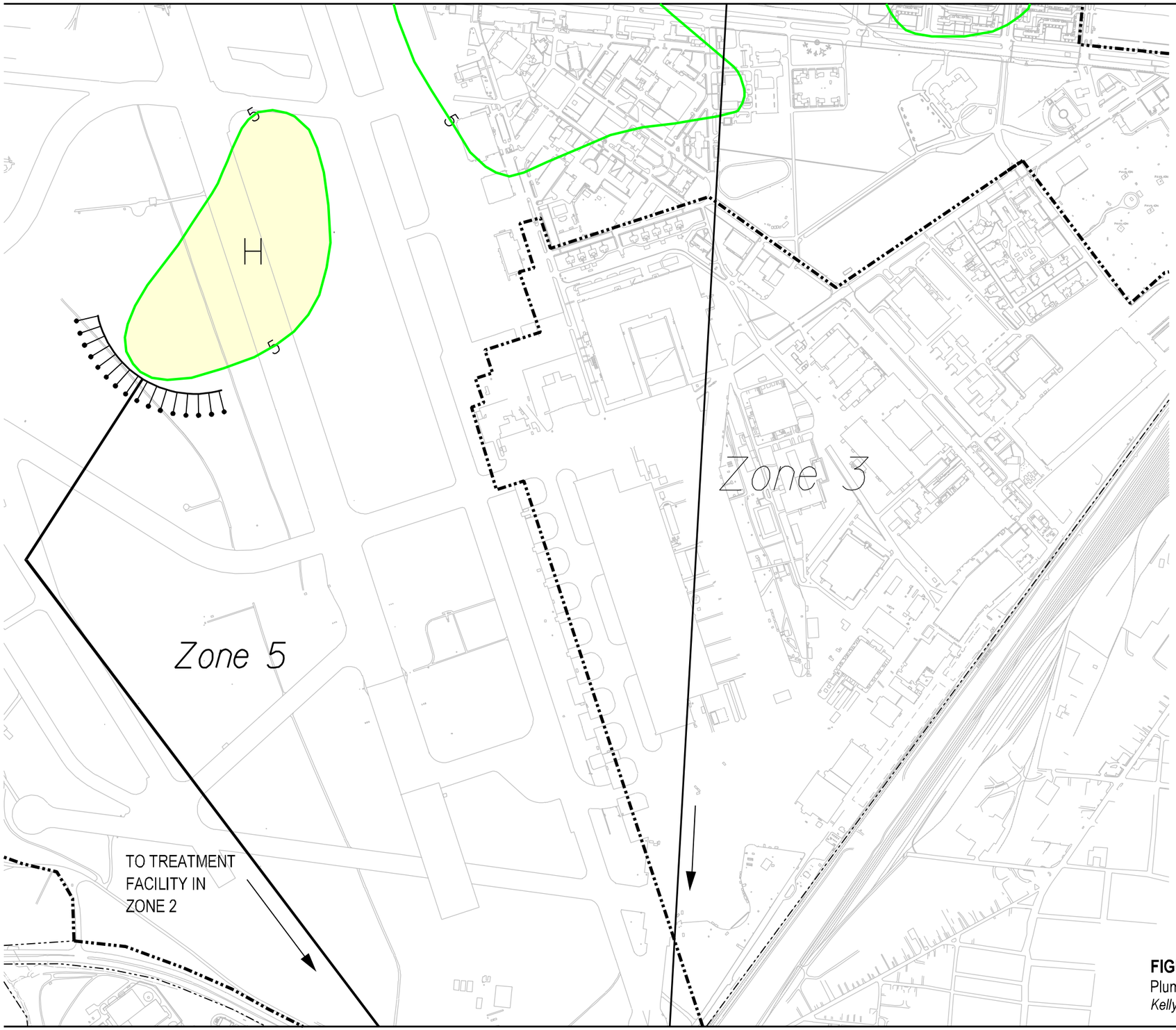
0 400' 800' 1200'

FIGURE 6.6

Plume D - Perimeter Area Containment and Ex Situ Treatment

Kelly AFB, San Antonio, Texas

CH2MHILL



LEGEND

Plume

Zone 5 Boundary

Pump and Treat

Extraction Well (16)

Transfer Piping

Notes:

1. Location of all equipment and systems are approximate for this conceptual design.
2. All equipment and systems shown on this diagram are proposed and do not currently exist at the site.
3. See Figure 6.2 for location within Zone 5.
4. Shaded portions of figure are plumes that are targeted for treatment.

N

0 400' 800' 1200'

AIRFORCE BASE CONVERSION AGENCY

FIGURE 6.7
Plume H - Perimeter Area Containment and Ex Situ Treatment
Kelly AFB, San Antonio, Texas

CH2MHILL

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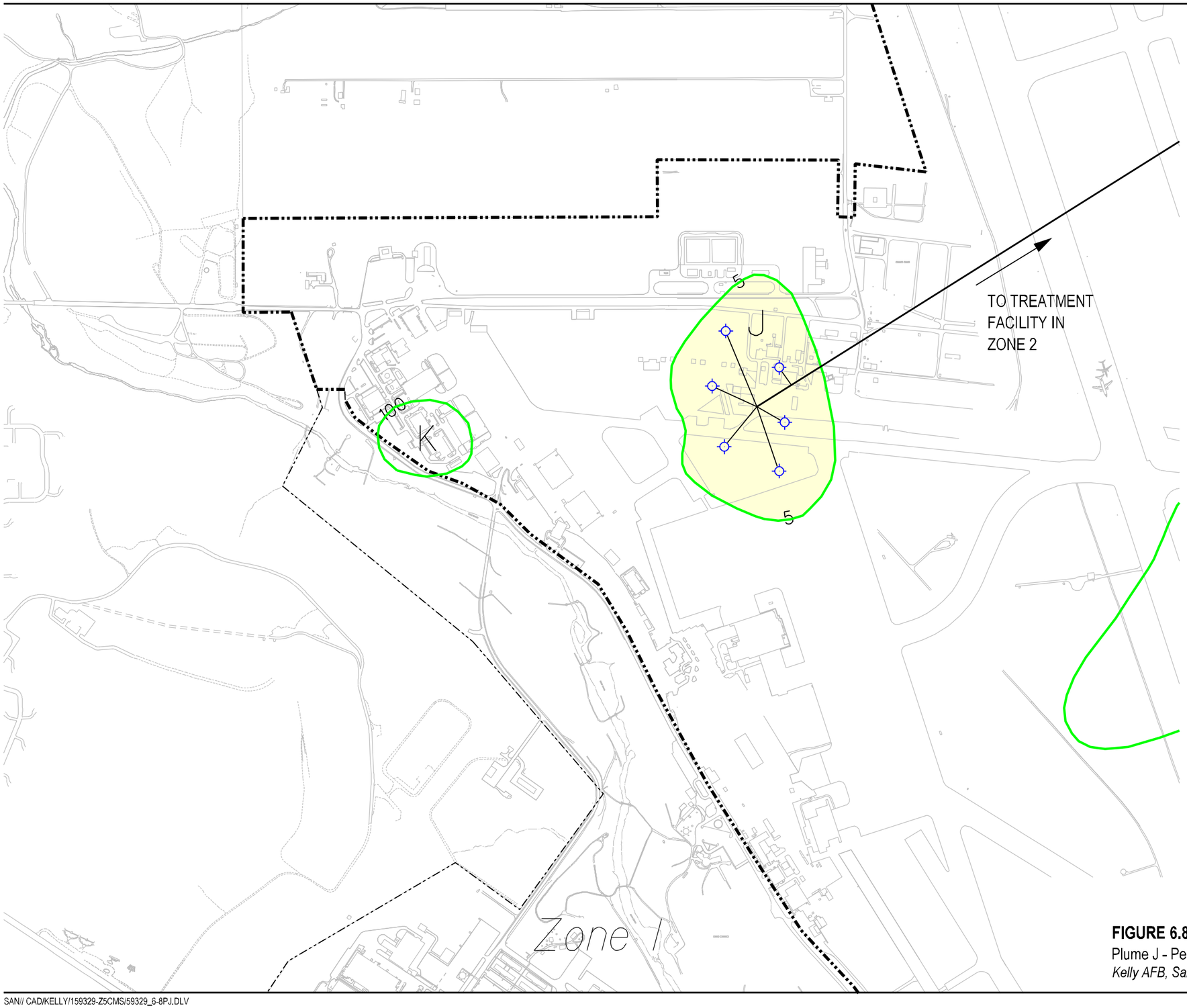
28-DEC-2001



LEGEND

Plume

Zone 5 Boundary

In Situ Treatment

Recovery Well

Notes:

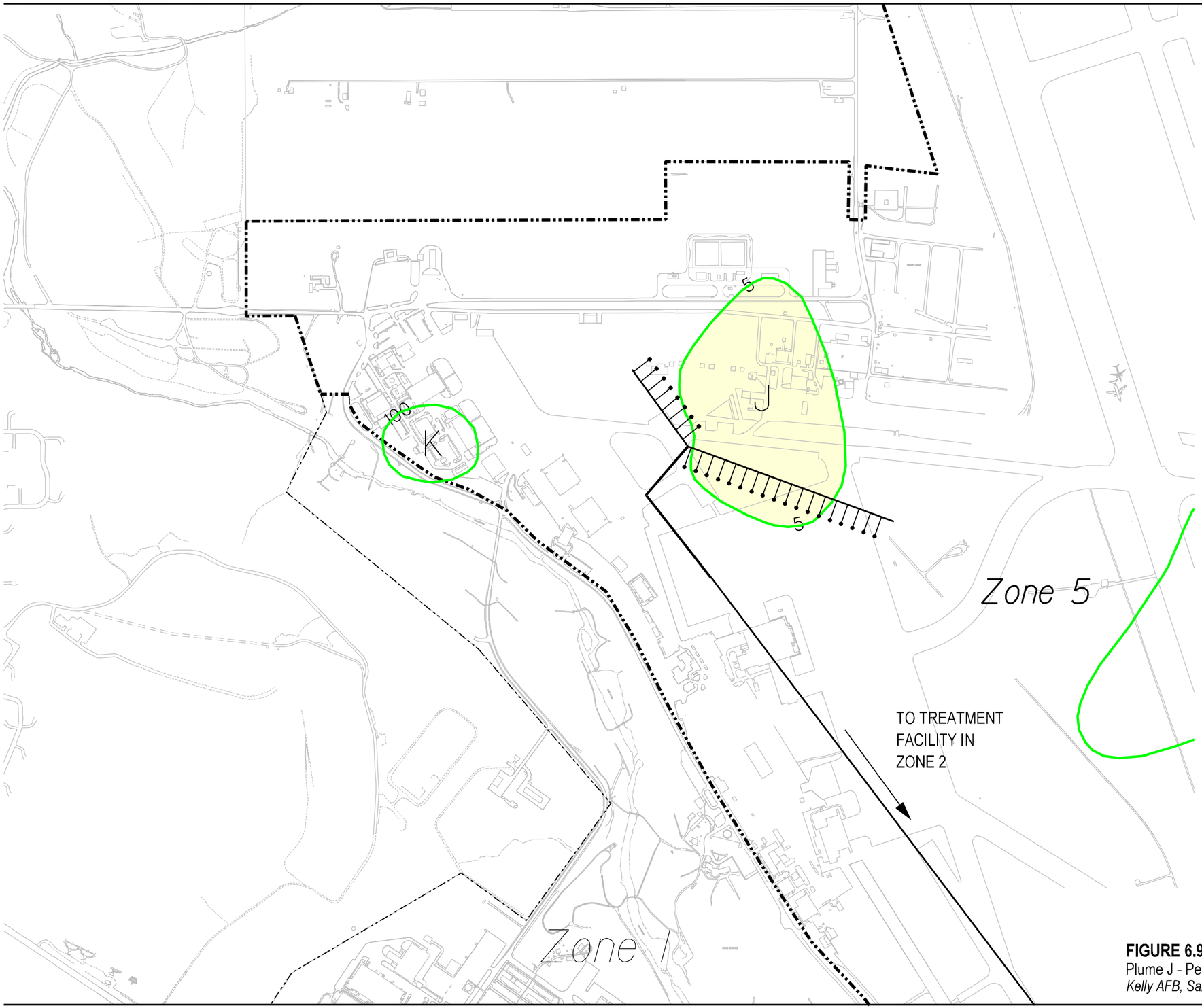
1. Location of all equipment and systems are approximate for this conceptual design.
2. All equipment and systems shown on this diagram are proposed and do not currently exist at the site.
3. See Figure 6.2 for location within Zone 5.
4. Shaded portions of figure are plumes that are targeted for treatment.

N

0 400' 800' 1200'

FIGURE 6.8
Plume J - Perimeter Area In Situ Treatment
Kelly AFB, San Antonio, Texas

CH2MHILL



LEGEND

Plume

Zone 5 Boundary

Pump and Treat

Extraction Well (26)

Transfer Piping

Notes:

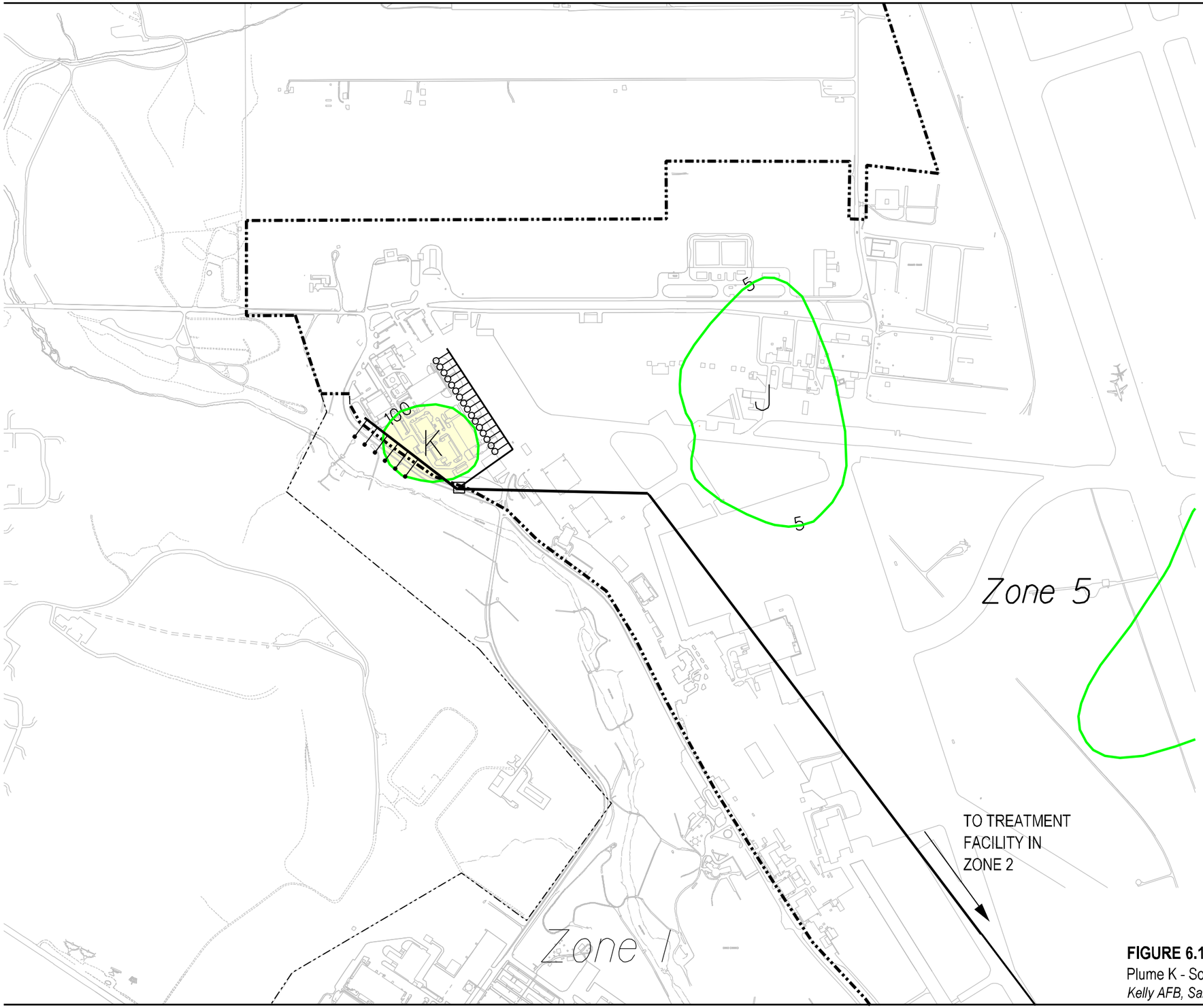
1. Location of all equipment and systems are approximate for this conceptual design.
2. All equipment and systems shown on this diagram are proposed and do not currently exist at the site.
3. See Figure 6.2 for location within Zone 5.
4. Shaded portions of figure are plumes that are targeted for treatment.

N

0 400' 800' 1200'

FIGURE 6.9
Plume J - Perimeter Area Containment and Ex Situ Treatment
Kelly AFB, San Antonio, Texas

CH2MHILL



LEGEND

Plume

Zone 5 Boundary

In Situ Treatment

Injection Well (16)

Extraction Well (6)

Transfer Piping

Nutrient/Substrate Mixing Tanks and Process Control Facility

Notes:

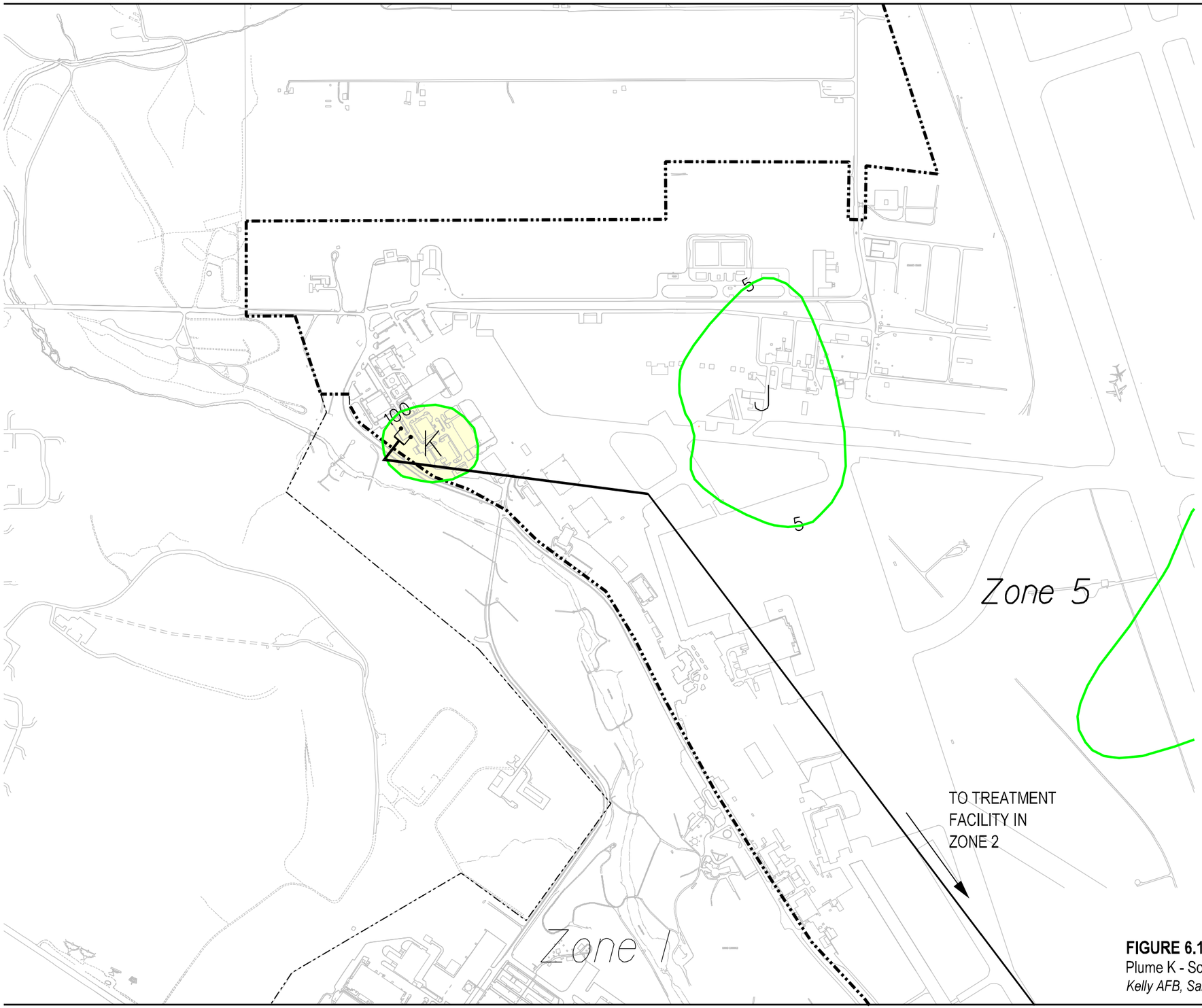
1. Location of all equipment and systems are approximate for this conceptual design.
2. All equipment and systems shown on this diagram are proposed and do not currently exist at the site.
3. See Figure 6.2 for location within Zone 5.
4. Shaded portions of figure are plumes that are targeted for treatment.

N

0 400' 800' 1200'

FIGURE 6.10
Plume K - Source Area In Situ Treatment
Kelly AFB, San Antonio, Texas

CH2MHILL



LEGEND

Plume

Zone 5 Boundary

Pump and Treat

Extraction Well (2)
Transfer Piping

Notes:

1. Location of all equipment and systems are approximate for this conceptual design.
2. All equipment and systems shown on this diagram are proposed and do not currently exist at the site.
3. See Figure 6.2 for location within Zone 5.
4. Shaded portions of figure are plumes that are targeted for treatment.

N

0 400' 800' 1200'

AIRFORCE BASE CONVERSION AGENCY

FIGURE 6.11
Plume K - Source Area Containment and Ex Situ Treatment
Kelly AFB, San Antonio, Texas

CH2MHILL

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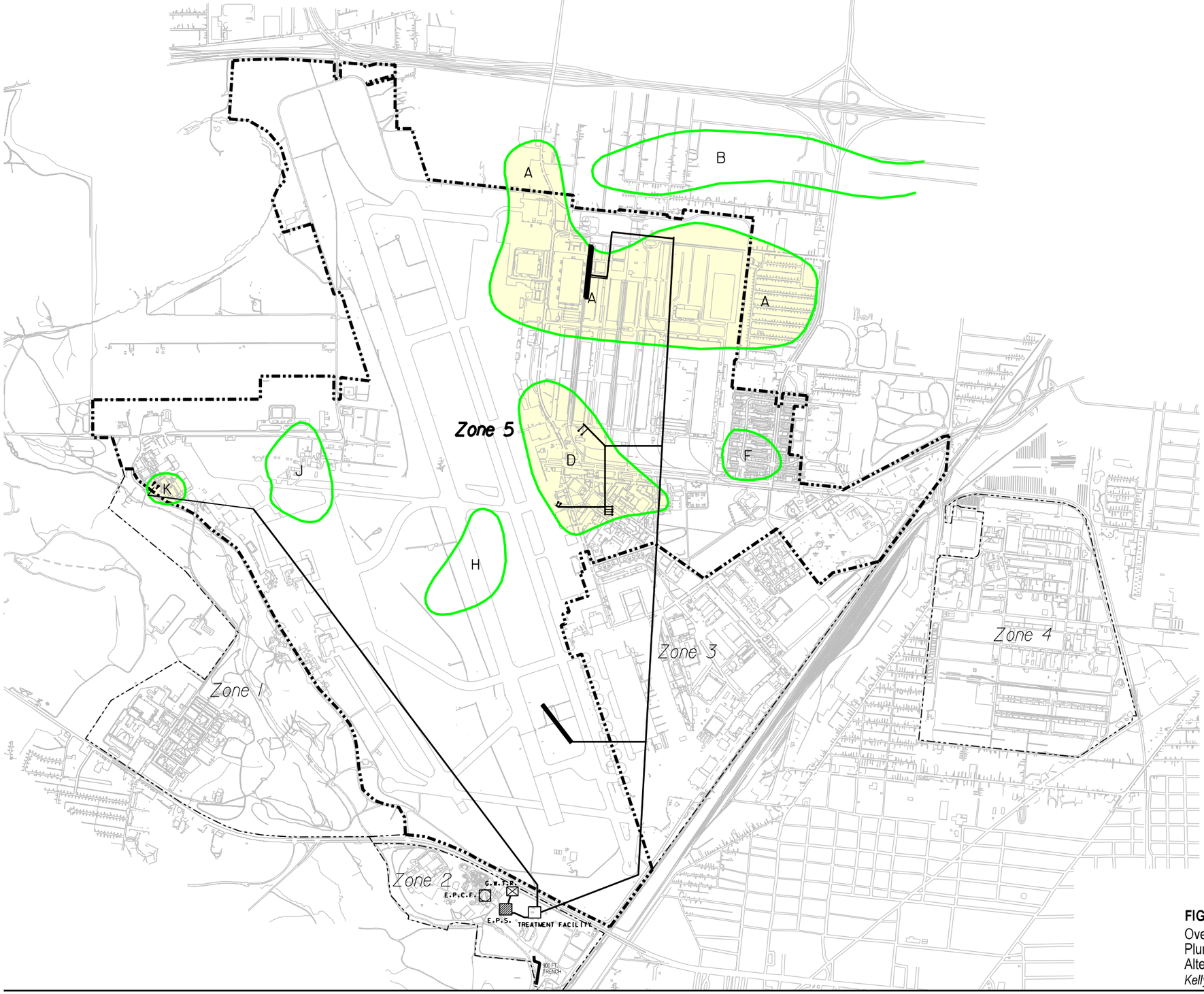
28-DEC-2001



LEGEND

Plume A - On and Offbase TCE.

Plume B - Offbase PCE (Not addressed by this CMS).

Plume D - SS045 (S-10) and 1600 Area TCE, PCE, 1,2-DCE.

Plume F - Low Concentration PCE/TCE.

Plume H - Central Runway TCE.

Plume J - KY028 (1100 Area) PCE, TCE.

Plume K - West Chlorobenzene.

Zone 5 Boundary

Extraction Well (14)
Transfer Piping

Trench

Treatment Facility

Effluent Polishing System (E.P.S.)

Environmental Pollution Control Facility

Zone 1, 2, 3 Groundwater Treatment Plant

Notes:

1. Shaded portions of figure are plumes that will be treated via the proposed Zone 5 treatment system. The unshaded plumes will be treated either through natural attenuation or the Zone 1, 2, 3, Groundwater Treatment System Plant (GWTP).

N

0 1000' 2000' 3000'

AIRFORCE BASE CONVERSION AGENCY

FIGURE 6.12
Overall View of
Plume Treatment Process
Alternative 3
Kelly AFB, San Antonio, Texas

CH2MHILL

LEGEND

Plume A - On and Offbase TCE.

Plume B - Offbase PCE (Not addressed by this CMS).

Plume D - SS045 (S-10) and 1600 Area TCE, PCE, 1,2-DCE.

Plume F - Low Concentration PCE/TCE.

Plume H - Central Runway TCE.

Plume J - KY028 (1100 Area) PCE, TCE.

Plume K - West Chlorobenzene.

Zone 5 Boundary

Injection Well (14)

Extraction Well (96)

Transfer Piping

Trench

Bioremediation System

Treatment Facility

Effluent Polishing System (E.P.S.)

Environmental Pollution Control Facility

Zone 1, 2, 3 Groundwater Treatment Plant

Notes:

1. Shaded portions of figure are plumes that will be treated via the proposed Zone 5 treatment system. The unshaded plumes will be treated either through natural attenuation or the Zone 1, 2, 3, Groundwater Treatment System Plant (GWTP).

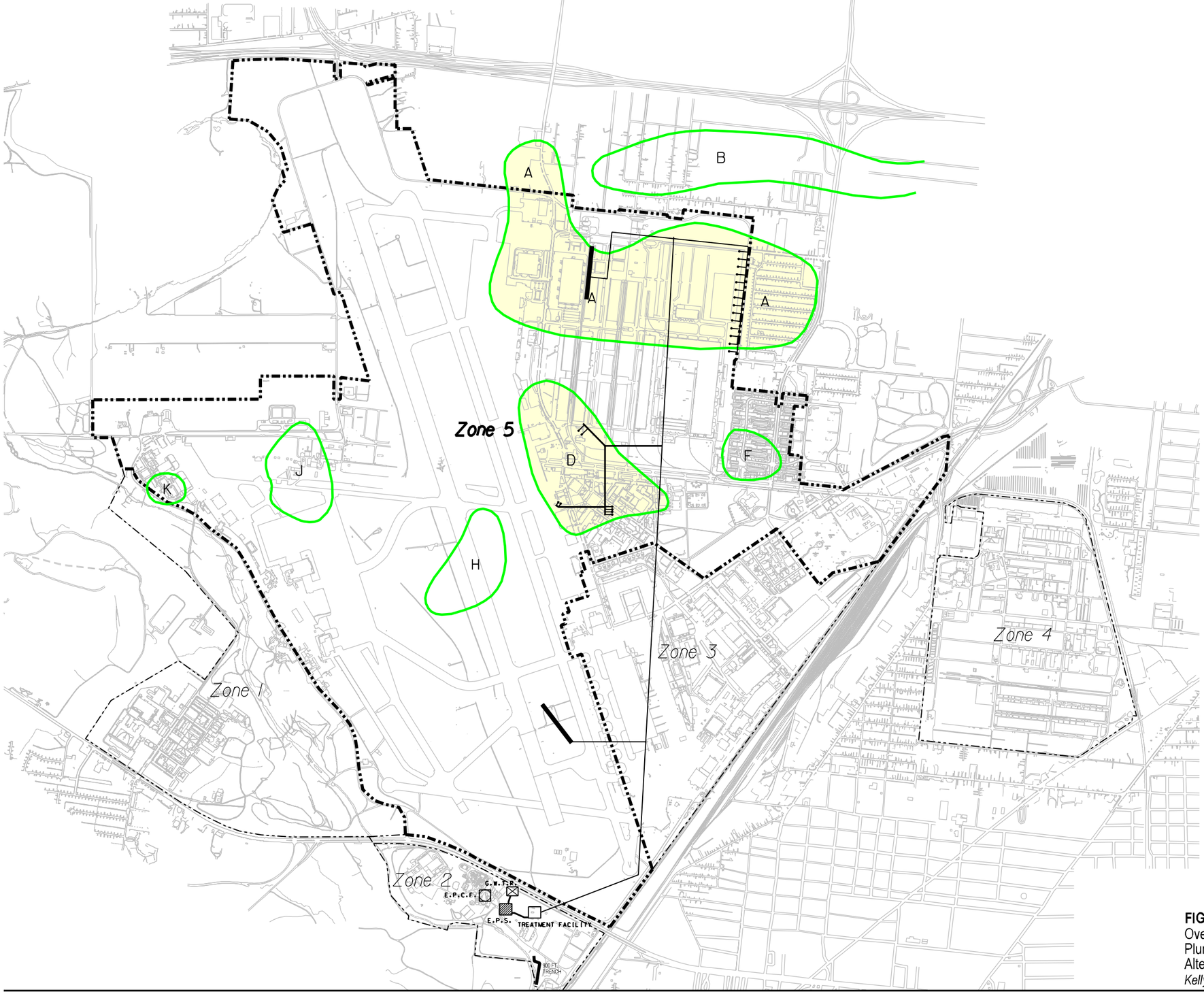
N

0 1000' 2000' 3000'

FIGURE 6.13
Overall View of
Plume Treatment Process
Alternative 4
Kelly AFB, San Antonio, Texas

AIR FORCE BASE CONVERSION AGENCY

CH2MHILL



LEGEND

Plume A - On and Offbase TCE.

Plume B - Offbase PCE (Not addressed by this CMS).

Plume D - SS045 (S-10) and 1600 Area TCE, PCE, 1,2-DCE.

Plume F - Low Concentration PCE/TCE.

Plume H - Central Runway TCE.

Plume J - KY028 (1100 Area) PCE, TCE.

Plume K - West Chlorobenzene.

Zone 5 Boundary

Extraction Well (26)
Transfer Piping

Trench

Treatment Facility

Effluent Polishing System (E.P.S.)

Environmental Pollution Control Facility

Zone 1, 2, 3 Groundwater Treatment Plant

Notes:

1. Shaded portions of figure are plumes that will be treated via the proposed Zone 5 treatment system. The unshaded plumes will be treated either through natural attenuation or the Zone 1, 2, 3, Groundwater Treatment System Plant (GWTP).

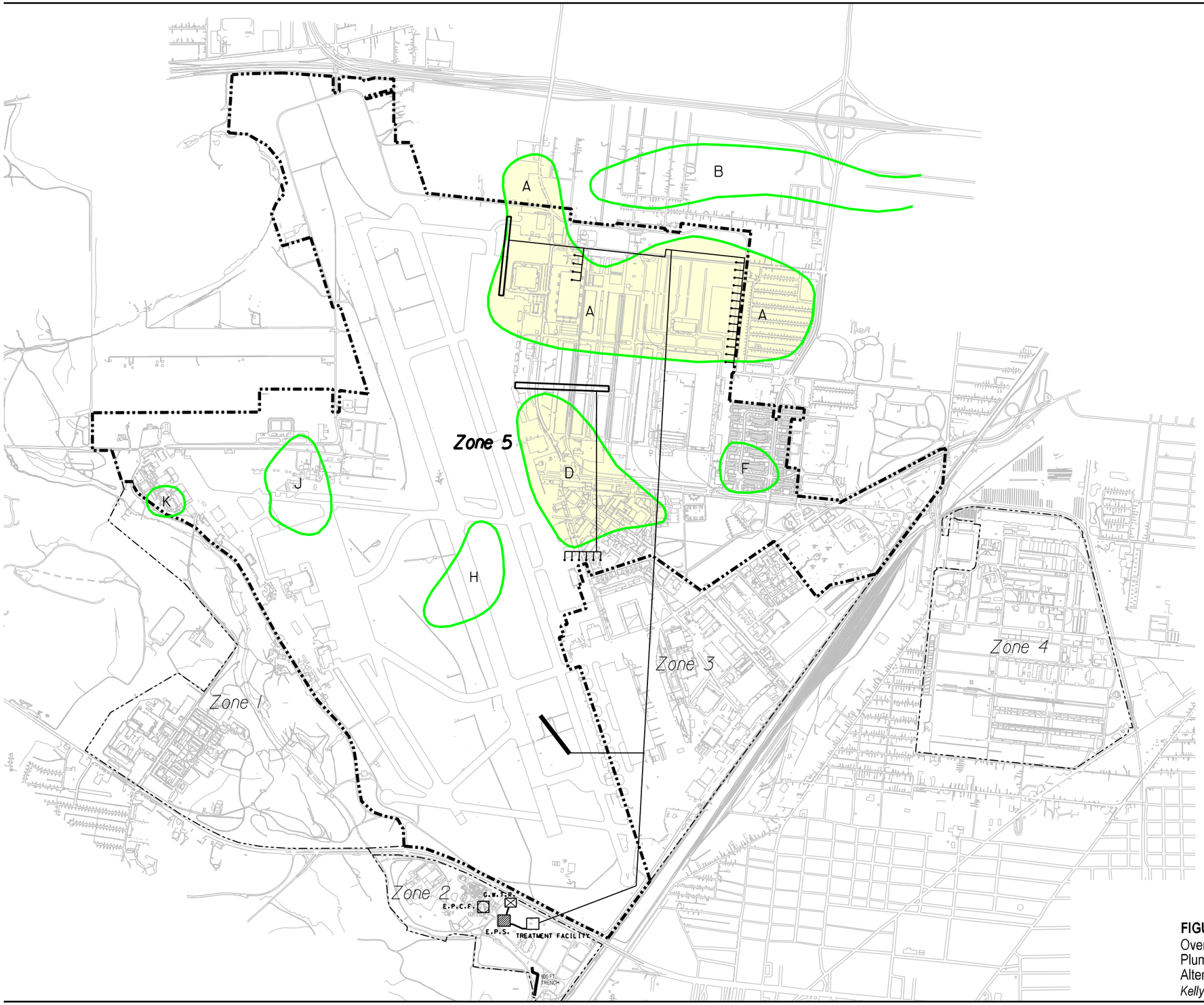
N

0 1000' 2000' 3000'

FIGURE 6.14
Overall View of
Plume Treatment Process
Alternative 5
Kelly AFB, San Antonio, Texas

AIRFORCE BASE CONVERSION AGENCY

CH2MHILL



LEGEND

Plume A - On and Offbase TCE.

Plume B - Offbase PCE (Not addressed by this CMS).

Plume D - SS045 (S-10) and 1600 Area TCE, PCE, 1,2-DCE.

Plume F - Low Concentration PCE/TCE.

Plume H - Central Runway TCE.

Plume J - KY028 (1100 Area) PCE, TCE.

Plume K - West Chlorobenzene.

Zone 5 Boundary

Extraction Well (28)
Transfer Piping

Trench

Bioremediation System

Treatment Facility

Effluent Polishing System (E.P.S.)

Environmental Pollution Control Facility

Zone 1, 2, 3 Groundwater Treatment Plant

Notes:

1. Shaded portions of figure are plumes that will be treated via the proposed Zone 5 treatment system. The unshaded plumes will be treated either through natural attenuation or the Zone 1, 2, 3, Groundwater Treatment System Plant (GWTP).

N

0 1000' 2000' 3000'

AIRFORCE BASE CONVERSION AGENCY

FIGURE 6.15
Overall View of
Plume Treatment Process
Alternative 7
Kelly AFB, San Antonio, Texas

CH2MHILL

SECTION 7.0

Detailed Analysis of Alternatives

7.1 Introduction

The detailed analysis of alternatives presents the relevant information needed to compare the remedial alternatives assembled for the the Zone 5 groundwater. The detailed analysis of alternatives follows the development and screening of alternatives, and precedes the selection of a final remedy. The extent to which alternatives are fully evaluated during the detailed analysis is influenced by the available data and the number and types of alternatives being analyzed.

Detailed analysis of alternatives consists of the following components:

- A detailed evaluation of each alternative against seven of the CERCLA evaluation criteria
- A comparative evaluation.

7.1.1 Evaluation Criteria

In accordance with the NCP, remedial actions must accomplish the following:

- Protect human health and the environment
- Attain ARARs or provide grounds for invoking a waiver of ARARs that cannot be achieved
- Be cost-effective
- Utilize permanent solutions and alternative treatment technologies or resource-recovery technologies to the maximum extent practicable
- Satisfy the preference for treatment that reduces TMV as a principal element.

In addition, the NCP emphasizes long-term effectiveness and related considerations including the following:

- The long-term uncertainties associated with land disposal
- The goals, objectives, and requirements of the SDWA
- The persistence, toxicity, and mobility of hazardous substances and their constituents, and their propensity to bio-accumulate
- The short-and long-term potential for adverse health effects from human exposure
- Long-term maintenance costs
- The potential for future remedial action costs if the selected remedial action fails

- The potential threat to human health and the environment associated with excavation, transportation, redisposal, or containment.

Provisions of the NCP require that each alternative be evaluated against nine criteria listed in 40 CFR 300.430(e)(9). These criteria were published in the March 8, 1990, *Federal Register* (55 FR 8666), to provide grounds for comparison of the relative performance of the alternatives and to identify their advantages and disadvantages. This approach is intended to provide sufficient information to adequately compare the alternatives and to select the most appropriate alternative for implementation at the site as a remedial action. The following are the evaluation criteria:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of TMV through treatment
- Short-term effectiveness
- Implementability
- Cost
- Community Acceptance
- State Acceptance.

In addition, because this document also serves to satisfy the Kelly AFB obligations under NEPA, the detailed analysis considers potential environmental impacts that are not otherwise addressed by CERCLA criteria. The evaluation of environmental impacts is made in Section 7.4.

The nine CERCLA criteria are divided into three groups: threshold, balancing, and modifying criteria. Threshold criteria must be met by a particular alternative for it to be eligible for selection as a remedial action. There is little flexibility in meeting the threshold criteria: either they are met by a particular alternative, or that alternative is not considered acceptable. The two threshold criteria are overall protection of human health and the environment, and compliance with ARARs. If ARARs cannot be met, a waiver may be obtained in situations where one of the six exceptions listed in the NCP occurs (see 40 CFR 300.430 (f)(1)(ii)(C)(1 to 6).

Unlike the threshold criteria, the five balancing criteria weigh the trade-offs between alternatives. A low rating on one balancing criterion can be compensated by a high rating on another. The five balancing criteria include the following:

- Long-term effectiveness and permanence
- Reduction of TMV through treatment
- Short-term effectiveness
- Implementability

- Cost.

The modifying criteria are community and state acceptance. These are evaluated following public comment and are used to modify the selection of the recommended alternative. The threshold and balancing evaluation criteria are briefly described below. The modifying criteria will be evaluated after the public and the regulatory agencies have had an opportunity to review this CMS and the proposed plan.

7.1.1.1 Threshold Criteria

To be eligible for selection, an alternative must meet the two threshold criteria described below, or in the case of ARARs, must justify why a waiver is appropriate.

- **Overall Protection of Human Health and the Environment.** Protectiveness is the primary requirement that remedial actions must meet under CERCLA. A remedy is protective if it adequately eliminates, reduces, or controls all current and potential risks posed by the site through each exposure pathway. The assessment against this criterion describes how the alternative achieves and maintains protection of human health and the environment.

- **Compliance with ARARs.** Compliance with ARARs is one of the statutory requirements of remedy selection. ARARs are cleanup standards, standards of control, and other substantive environmental statutes or regulations that are either "applicable" or "relevant and appropriate" to the CERCLA cleanup action (42 United States Code 9621 [d] [2]). Applicable requirements address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances at a CERCLA site. Relevant and appropriate requirements are those that while not applicable, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to environmental or technical factors at a particular site. The assessment against this criterion describes how the alternative complies with ARARs or presents the rationale for waiving an ARAR. ARARs can be grouped into three categories:

  -- **Chemical-specific** ARARs are health- or risk-based numerical values or methodologies that, when applied to site-specific conditions, establish the amount or concentration of a chemical that may remain in or be discharged to the environment.

  -- **Location-specific** ARARs restrict the concentration of hazardous substances or the conduct of activities solely because they are in specific locations, such as flood plains, wetlands, historic places, and sensitive ecosystems or habitats.

  -- **Action-specific** ARARs include technology- or activity-based requirements that set controls, limits, or restrictions on design performance of remedial actions or management of hazardous constituents.

7.1.1.2 Balancing Criteria

The five criteria listed below represent the criteria upon which the detailed evaluation and comparative analysis of alternatives is based.

- **Long-Term Effectiveness and Permanence.** This criterion reflects CERCLA's emphasis on implementing remedies that will ensure protection of human health and the

environment in the long term as well as in the short term. The assessment of alternatives against this criterion evaluates the residual risks at a site after completing a remedial action or enacting a No Action Alternative and includes evaluation of the adequacy and reliability of controls.

- **Reduction of TMV through Treatment.** This criterion addresses the statutory preference for remedies that employ treatment as a principal element. The assessment against this criterion evaluates the anticipated performance of the specific treatment technologies an alternative may employ. The criterion is specific to evaluating only how treatment reduces TMV and does not address containment actions such as capping.

- **Short-Term Effectiveness.** This criterion addresses short-term impacts of the alternatives. The assessment against this criterion examines the effectiveness of alternatives in protecting human health and the environment (i.e., minimizing any risks associated with an alternative) during the construction and implementation of a remedy until the response objectives have been met.

- **Implementability.** The assessment against this criterion evaluates the technical and administrative feasibility of the alternative and the availability of the goods and services needed to implement it.

- **Cost.** Cost encompasses all engineering, construction, and O&M costs incurred over the life of the project. The assessment against this criterion is based on the estimated present worth of these costs for each alternative. Present worth is a method of evaluating expenditures such as construction and O&M that occur over different lengths of time. This allows costs for remedial alternatives to be compared by discounting all costs to the year that the alternative is implemented. The present worth of a project represents the amount of money, which, if invested in the initial year of the remedy and disbursed as needed, would be sufficient to cover all costs associated with the remedial action. As stated in the RI/FS guidance (USEPA, 1988), these estimated costs are expected to provide an accuracy of plus 50 percent to minus 30 percent (+50 percent to –30 percent). Appendix K provides a breakdown of the cost estimate for each of the site SS003 (S-1) alternatives and Appendix J provides a breakdown of cost estimates for the Zone 5 groundwater alternatives.

The level of detail required to analyze each alternative against these evaluation criteria depends on the nature and complexity of the site, the types of technologies and alternatives being considered, and other project-specific considerations. The analysis is conducted in sufficient detail to understand the significant aspects of each alternative and to identify the uncertainties associated with the evaluation.

7.2 Detailed Evaluation of Groundwater Remediation Alternatives

The following alternatives for groundwater remediation at Zone 5 were developed, as described in Section 6.2:

- Alternative 1 – No Further Action

- Alternative 2 – Monitored Natural Attenuation
- Alternative 3 – Source Control
- Alternative 4 – Source Ex Situ and In Situ Treatment, Perimeter Control and Off Base Control
- Alternative 5 – Source and Perimeter Control
- Alternative 6 – Targeted Source and Perimeter Control
- Alternative 7 – Source Ex Situ and In Situ Treatment and Perimeter Control.
- Alternative 8 – In situ Oxygen Treatment for Plume A Source and Permeable Reactive Wall Treatment at Perimeter
- Alternative 9 – In situ Bioremediation Treatment for Plume A Source and Permeable Reactive Wall Treatment at Perimeter

These alternatives were evaluated in detail using the CERCLA criteria discussed in Section 7.1.1.

The detailed evaluation of the CERLCA criteria is presented in Table 7.1.

7.2 Comparative Evaluation of Groundwater Remediation Alternatives

7.2.1 Overall Protection of Human Health and Environment

Protection of human health and the environment is the basis for the RAOs as well as a "threshold" evaluation criterion (that is, the alternative must be protective in order TBC for selection.) Alternatives 2 through 7 all meet the threshold criterion of being protective of human health and the environment. The RAOs pertaining to groundwater are those numbered 1 through 4 in Section 4.3 and are summarized below:

1. Both on base and off base, prevent use of groundwater containing contaminants at concentrations that exceed MCLs or, where those are not available, Texas groundwater MSCs.

2. Reduce or prevent further migration of contaminated groundwater (defined as groundwater with contaminant concentrations that exceed MCLs or, where those are not available, Texas groundwater MSCs) from on base areas to off base areas.

3. Restore off base groundwater to MCLs or, where those are not available, to Texas groundwater MSCs, within a reasonable time frame.

4. Restore on base groundwater to MCLs or, where those are not available, to Texas groundwater MSCs, within a reasonable time frame. If that time frame exceeds 20 years, establish ACLs that are no greater than existing contaminant concentrations and ensure that those ACLs are met during the interim time period.

Alternatives 2 through 9 achieve the objective of preventing the use of groundwater containing contaminants exceeding MCLs or MSCs because they all would use administrative controls (such as deed restrictions) to restrict the use of the shallow groundwater.

Alternatives 3 through 9 achieve the objective of substantially reducing or eliminating further migration of contaminants through the groundwater. These alternatives would achieve this objective by intercepting or eliminating (through in situ bioremediation) contaminants in the groundwater at various locations both on and off base.

In areas where contamination has already migrated off base, the time to restore groundwater quality to beneficial use is estimated to be about 26 years for the alternatives that do not include active remediation (Alternatives 1 and 2). Alternatives that establish hydraulic gradient barriers at the base boundary (Alternatives 5 and 7) would restore the groundwater quality to beneficial use in off base areas in approximately 21 years. Establishment of off base extraction wells, in conjunction with hydraulic barriers along the base boundary (Alternative 4) would not restore the groundwater quality to beneficial use any faster than establishment of hydraulic gradient barriers at the base boundary alone (21 years).

Under all alternatives, in areas subject to base closure (essentially the area east of the runway as shown in Figure 2.1), groundwater would eventually be restored to PRGs. Alternatives 3 through 9 would achieve this objective in the least amount of time (21 to 22 years) while Alternatives 1 and 2 would achieve this objective over the longest time frame (almost 30 years).

In areas that will remain under DoD control, Alternatives 3, through 7 would reduce contamination levels to PRGs in about 22 years. Alternatives 1 and 2 would take about 30 years to achieve this result. Where Plumes H and J are allowed to naturally attenuate (Alternatives 1, 2, 3, 5, 6 and 7), the time to reduce contamination levels to PRGs is about 6.5 years. Under the active remediation option (Alternative 4), Plumes H and J would take about 5 years to reduce contamination levels to PRGs, which is not a significant improvement over allowing them to naturally attenuate. Contamination levels in Plume K would be reduced to PRGs in 5 to 10 years regardless of whether the plume is actively remediated or allowed to naturally attenuate.

Source control and upgrade of the existing perimeter systems as necessary (Alternatives 3, 5 and 7) would be effective at reducing off base contaminant levels in a reasonable time frame (RAOs 2 and 3) and of those alternatives, only Alternatives 5 and 7 would be effective at reducing on base contaminant levels (RAO 4).

Alternatives 8 and 9 achieve the objective of substantially reducing or eliminating further migration of contaminants through the groundwater. These alternatives would achieve this by intercepting and treating the contaminants in the groundwater associated with Plume A and along the base perimeter. Treating the source area and base perimeter will eliminate or reduce further releases and prevent further potential for off-base migration of contamination.

7.2.2 Compliance with ARARs

Compliance with ARARs is also a threshold criterion. To be selected, an alternative must meet ARARs. Because Kelly AFB is not formally subject to CERCLA, the use of the CERCLA waiver process is not appropriate.

Alternatives 2 through 9 would all meet the threshold criterion for compliance with ARARs. Alternatives 3 through 9 are expected to comply with the ARARs related to treated groundwater discharge by meeting NPDES permit discharge limits. Air emissions (if any) would meet concentration and volume limits for discharge of VOCs under the state standard exemption for remediation.

7.2.3 Long-Term Effectiveness

The long-term effectiveness of the seven alternatives is highly dependent on how well the alternative reduces the residual contamination in the shallow aquifer. All alternatives would be effective in the long term, although each alternative would vary in the time frame needed to meet the objectives (as discussed in Section 7.2.1). The alternatives also vary in the methods used to achieve the RAOs. Alternatives 1 and 2 rely solely on monitored natural attenuation, Alternatives 3, 5, and 6 have components of monitored natural attenuation, and hydraulic barriers, and Alternatives 4 and 7 have components of monitored natural attenuation, in situ treatment, and hydraulic barriers. Alternatives 8 and 9 would be effective at reducing the mass of contaminants in the aquifer. These alternatives could efficiently treat the affected groundwater, but would not eliminate the migration of residual soil contamination into the groundwater.

Monitored natural attenuation of CVOCs proceeds by mechanisms that are generally irreversible and in this sense, natural attenuation is an adequate and reliable control once the concentrations have been reduced to acceptable levels. There is no residual risk once the concentrations have been reduced to acceptable levels.

Hydraulic barriers are generally reversible. If the hydraulic barriers are eliminated (i.e., if pumping is stopped) groundwater contaminant concentrations will return to some level above that which was observed during active pumping (at least until the contaminants contained in the aquifer sediments are reduced to levels that no longer pose a risk). Hydraulic barriers can develop discontinuities due to gradual reduction in pumping rates caused by such things as clogging of well screens, wear and tear on pump impellers, etc. Discontinuities could also be caused by seasonal variations in groundwater flow (both direction and volume) which could change the effectiveness of the hydraulic barriers. Hydraulic barriers are both adequate and reliable methods of groundwater contaminant migration control as long as groundwater flow parameters are measured and proper maintenance of the wells and pumps is performed. Once the concentrations of contaminants in the aquifer sediments have been reduced to acceptable levels (either through the flushing process established by the pumping system or through natural attenuation processes), there is no residual risk.

In situ biodegradation is generally irreversible and is an adequate and reliable control once contaminant levels have been reduced to acceptable levels. Implementation of in situ biodegradation of CVOCs can be difficult due to heterogeneities in the aquifer and the refractory nature of CVOCs in general. Many of the same concerns regarding

implementation of hydraulic barriers are also factors affecting implementation of in situ biodegradation. Once the concentrations of contaminants in the aquifer sediments have been reduced to acceptable levels there is no residual risk.

7.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternatives 1 and 2 do not include active treatment to reduce the TMV of contaminants. VOCs occurring in the plumes would attenuate naturally over time.

Alternatives 3 through 7 include active treatment that would reduce toxicity, mobility, and volume of contaminants in the groundwater through the application of UV oxidation and in situ bioremediation. These remediation technologies degrade contaminants to harmless by-products. The chemical reactions that occur are not reversible. Alternatives 8 and 9 all involve in situ treatment to reduce the toxicity, mobility, and volume of contamination in the groundwater with a removal effectiveness of nearly 100 percent.

As summarized in Table 7.5, each of the active remediation alternatives would remove or destroy about the same amount of VOCs over the life of the remediation activity. Alternative 6 would remove or destroy the least (about 440 lb) while Alternative 4 would remove or destroy the most (about 530 lb).

UV oxidation will provide nearly complete destruction of the contaminants. Residuals from a UV oxidation system would generally consist of small quantities of miscellaneous secondary waste materials such as spent filters, flocculator/clarifier sludge and waste materials incidental to the removal of sediment from the system influent. Inert salts (byproducts of pH adjustment) and spent ion exchange resin may also be generated in some of the existing GWTP systems. Residuals are not anticipated from the in situ bioremediation systems since the actual treatment occurs in situ.

7.2.5 Short-Term Effectiveness

There would not be any significant effects on workers, the community, or the environment during remediation for any of the seven alternatives.

The total concentrations of contaminants in the plumes is relatively small (averaging about 10 to 20 ppb per contaminant). The original sources that fed these plumes would have been relatively minor releases (no more than an average of about 0.5 gal per year). This is likely why the RI and subsequent investigations could not identify sources for many of the low concentration VOC plumes. Because continued releases of such small concentrations of VOCs either from vadose zone, aquifer sediments or sewer line leaks, could continue for decades, or cannot be located, it is not possible to predict when natural attenuation will result in a return of groundwater to drinking water standards for onsite groundwater near the origins of the plumes. Consequently, it may take a very long time (30 years) for on base groundwater contaminant concentrations to return to PRGs. It is most probable that there will be a gradual decline in concentrations near the original sources as a result of contaminant dispersion and better management practices for hazardous substances. However, under Alternative 2 there is a possibility that there is a continuous source feeding many of the plumes, and these plumes would continue to expand [this is especially true for plume D which could take almost 30 years to reach steady state (Appendix G)]. The possibility that these plumes would continue to expand would make it difficult to achieve RAO Number 4 (Section 4.3) under Alternative 2.

Control of the highest concentration portion of the groundwater plumes is included in Alternatives 3 through 9. Control of the source areas is especially important because it allows natural attenuation to restore the on base and eventually the off base portions of the plumes in reasonable time frames. Alternative 6 does the least amount of source control because it does not include source control for Plumes D and K. This may not be acceptable for control of plume D, for the reasons outlined above, but is probably acceptable for Plume K because the contamination associated with Plume K is apparently stable if not diminishing in extent. Alternatives 3 through 5 and 9 would all control the source areas to the extent necessary to meet the RAOs. Alternatives 4, 7, and 9 would use in situ biological treatment for source control of plumes A, B, D and I. Although in situ treatment may be less implementable than the establishment of hydraulic barriers, the permanent elimination of contamination that these alternatives would offer would be beneficial.

Perimeter control is included in alternatives 3 through 9. This would result in reductions in the time frame for restoration of off base plumes. Alternatives 3 and 6 include perimeter control using the existing Zone 1 and 2 recovery well networks, upgraded to capture the entire Plume I. Alternatives 8 and 9 use perimeter control for Plume A. Perimeter control of Plume A would reduce the time for remediation of the off base portion by about 5 years (Appendix G).

Off base collection and treatment of Plume B is included in Alternative 4. The extent of the off base portions of these plumes is currently poorly defined (although Kelly AFB is currently planning to augment the network of groundwater monitoring wells and establish the extent of the contamination). It is difficult to design a network of wells in the off base areas that would capture and remove the contaminants because of the potential size of the plumes.

Alternatives 1 and 2 would require the longest remediation time because they rely on no action and monitored natural attenuation for remediation. For remediation of contaminated groundwater on base, Alternatives 4 and 7 may achieve RAOs faster than Alternatives 3, 5, and 6 because they would eliminate the source area contamination. Alternatives 4 and 7 have the advantage of using both in-situ and pump and treat systems for source remediation in combination with pump and treat and existing GWTPs for perimeter control. Alternatives 3, 5, and 6 rely mainly on pump and treat, monitored natural attenuation, and existing GWTPs for on base (source and perimeter) groundwater remediation. Alternatives 8 and 9 would have the best overall short-term effectiveness for Plume A because they would eliminate the source of contamination and would allow for cessation of the active groundwater treatment sooner than Alternative 1.

7.2.6 Implementability

All alternatives can be implemented, however, there are technical issues associated with the alternatives that involve active remediation (Alternatives 3 through 9) related to the heterogeneous nature of the aquifer. All of the active remediation alternatives (Alternatives 3 through 7) involve pump and treat and will have some difficulties related to the relatively low hydraulic conductivity and heterogeneities in the area. Alternatives 4 and 7, 8 and 9, which include an in situ bioremediation component may have some difficulties in achieving uniform dispersion of substrates and/or nutrients into the aquifer. In general, Alternatives 3 through 9 all involve technologies, services, and materials that are readily available. In situ bioremediation (Alternatives , 7 8and 9) is a relatively new and innovative

technology, and most applications of this technology to date have been at relatively small remediation sites, and has not been proven on larger sites.

7.2.7 Cost

Table 7.2 presents the capital cost present worth for the nine alternatives. The lifetime of each alternative is also shown in Table 7.2. The discount rate for all alternatives is assumed to be 7.5 percent per year.

A detailed breakdown of the cost estimates for each component of the alternatives is provided in Appendix K. These cost estimates have been developed strictly for comparing the nine proposed alternatives. Final project costs will vary from the cost estimates. The final costs of the project and the resulting feasibility will depend on actual labor and material costs, competitive market conditions, actual site conditions, final project scope, the implementation schedule, the firm selected for final engineering design, and other variables. Because of these factors, project feasibility and funding needs must be reviewed carefully before specific financial decisions are made or project budgets are established to help ensure proper project evaluation and adequate funding.

The cost estimates are order-of-magnitude estimates having an intended accuracy range of plus 50 percent to minus 30 percent. The range applies to the alternatives as they are defined in Section 6.2 and does not account for changes in the scope of the alternatives. Selection of a specific technology or process as the recommended interim remedial alternative is not intended to limit flexibility during remedial design and implementation. It is intended to provide a basis for preparing cost estimates. The specific details of remedial actions and cost estimates for the remedial action would be refined during the design phase.

Alternative 1 has no cost. The cost for Alternative 2 is $1,590,000. The cost estimates for active remediation, Alternatives 3 through 7, range between $7.7 and $12.7 million. Alternatives 8 and 9 cost $8.0 million and $4.3 million, respectively.

7.2.8 State Acceptance

State acceptance will be assessed at the conclusion of the public comment period.

7.2.9 Community Acceptance

Community acceptance will be assessed at the conclusion of the public comment period.

7.3 NEPA Values

It is DoD policy to incorporate elements of NEPA into this CMS report. NEPA normally considers the environmental impacts of an action, such as impacts to environmental media, cultural resources, the ecosystem, and threatened and endangered species, as well as the cumulative impacts and any potential issues related to environmental justice. Environmental impacts that are of short-term nature are discussed in Section 7.2.5. The environmental impacts that are more long-term nature, including environmental justice issues, are discussed here. As described in the following bullets, none of the alternatives would be expected to have significant environmental impacts.

- Kelly AFB is located in an attainment area for all pollutants with established national and state air quality standards (per the Air Quality Control Region 13 of the Air Quality Division of the TNRCC); none of the alternatives are anticipated to generate air emissions sufficient to jeopardize the federal attainment status of the region.
- There are no known or suspected archaeological sites on Kelly AFB, and none of the alternatives would impact any structures, buildings, or objects eligible for listing on the National Register of Historic Places, and subject to the National Historic Preservation Act (36 CFR part 800).
- Due to the urban development in the project area, there is very little natural habitat to support wildlife. Therefore, none of the alternatives would impact on sensitive, protected, threatened or endangered species. Zone 5 is also located outside of the 100-year flood plain; and there are no wetlands in or around the proposed project site.
- Because the construction activity related to these alternatives is extremely small and in an already industrialized area, and because no effects to cultural or ecological resources are anticipated, no cumulative impacts are anticipated from any of the remedial action alternatives.
- None of the alternatives would increase Kelly AFB's draw from the Edwards Aquifer, and, therefore, would not impact the threatened and endangered species associated with this sole source aquifer. NEPA requirements for public involvement are similar to those for remedial actions, and thus are covered under the standard IRP public comment process.

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TABLE 7.1
Detailed Evaluation of Groundwater Alternatives
Kelly AFB, San Antonio, Texas

Alternative Description Criterion	Alternative 1 - No Further Action	Alternative 2 - Monitored Natural Attenuation	Alternative 3 – Source Control	Alternative 4 - Source Ex Situ and In Situ Treatment, Perimeter Control, and Off Base Control
1. Overall Protection of Human Health and the Environment (See Note 1)	Natural attenuation would ultimately reduce the mass of contamination, however, the time required may be fairly long, 30 years in some cases. Without monitoring, there would be no way to follow the progress.	Natural attenuation would ultimately reduce the mass of contamination, however, the time required may be fairly long, 30 years in some cases.	Pump and treat would control further contaminant migration from the source areas. Natural attenuation would ultimately reduce the mass of contamination, however, the time required may be almost 30 years.	Bioremediation, and pump and treat, of the groundwater would reduce or eliminate contamination and future off-site migration.
2. Compliance with ARARs (See Note 2)	This alternative does not invoke ARARs because no action is taken.	This alternative does not invoke ARARs because no action is taken.	Waste generated during drilling/trenching activities would be designated and disposed as appropriate. Treated groundwater would meet discharge permit concentration limits. Off-gas (if any) from the treatment of groundwater would meet state standards for a permit exemption. Solid waste generated from the groundwater treatment systems would be designated and disposed as appropriate.	Waste generated during all drilling/trenching activities would be designated and disposed as appropriate. A permit for injection of an organic substrate or an electron acceptor would be needed for in situ bioremediation of the groundwater. Treated groundwater would meet discharge permit concentration limits. Off-gas (if any) from the treatment of groundwater would meet state standards for a permit exemption. Solid waste generated from the groundwater treatment systems would be designated and disposed as appropriate.
3. Long-Term Effectiveness and Permanence				
(a) Magnitude of Residual Risks	This alternative would leave contamination in the groundwater at current concentration levels. Natural attenuation would ultimately reduce the mass of contamination to acceptable risk levels. Without monitoring, it would be difficult to determine when the groundwater contamination concentrations are within acceptable risk levels.	This alternative would leave contamination in the groundwater at current concentration levels. Natural attenuation would ultimately reduce the mass of contamination to acceptable risk levels.	Groundwater contaminant concentrations would be reduced to below PRGs.	Groundwater contaminant concentrations would be reduced to below PRGs.
(b) Adequacy and Reliability of Controls	Institutional controls preventing use of shallow groundwater in on base areas would be most reliable because of the continuing DoD control of the area. Institutional controls preventing use of shallow groundwater in off base areas would be least effective because of the many land owners involved and the difficulty in assuring land owners are in compliance with the controls. Nevertheless, existing institutional controls have generally been reliable in preventing use of shallow groundwater and are expected to continue to be so. Eventually, the groundwater would return to acceptable risk levels, but without monitoring to demonstrate this, the controls would have to continue indefinitely.	Institutional controls preventing use of shallow groundwater in on base areas would be most reliable because of the continuing DoD control of the area. Institutional controls preventing use of shallow groundwater in off base areas would be least effective because of the many land owners involved and the difficulty in assuring land owners are in compliance with the controls. Nevertheless, existing institutional controls have generally been reliable in preventing use of shallow groundwater and are expected to continue to be so. Eventually, the groundwater would return to acceptable risk levels, but may not occur for as much as 30 years.	Institutional controls preventing use of shallow groundwater in on base areas would be most reliable because of the continuing DoD control of the area. Institutional controls preventing use of shallow groundwater in off base areas would be least effective because of the many land owners involved and the difficulty in assuring land owners are in compliance with the controls. Nevertheless, existing institutional controls have generally been reliable in preventing use of shallow groundwater and are expected to continue to be so. This alternative would adequately control further migration of contaminants as long as the pump and treat systems are operated until natural attenuation diminishes the groundwater contamination to acceptable levels.	Institutional controls preventing use of shallow groundwater in on base areas would be most reliable because of the continuing DoD control of the area. Institutional controls preventing use of shallow groundwater in off base areas would be least effective because of the many land owners involved and the difficulty in assuring land owners are in compliance with the controls. Nevertheless, existing institutional controls have generally been reliable in preventing use of shallow groundwater and are expected to continue to be so. This alternative would adequately control further migration of contaminants as long as the aquifer is actively bioremediated and contaminated groundwater is extracted and treated.
4. Reduction of TMV Through Treatment				
(a) Treatment Processes Used	This alternative does not include active treatment.	This alternative does not include active treatment.	Groundwater will be extracted and treated by UV oxidation.	Groundwater will be bioremediated in place, extracted and treated by UV oxidation.
(b) Degree and Quantity of TMV Reduction	None	None	Total Estimated Mass removed over the life of the alternative: 450 lbs:	Total Estimated Mass removed over the life of the alternative: 530 lbs:
(c) Irreversibility of TMV Reduction	N/A	N/A	Natural attenuation and ex situ treatment are irreversible.	Natural attenuation, ex situ treatment, and in situ bioremediation are irreversible.

TABLE 7.1
Detailed Evaluation of Groundwater Alternatives
Kelly AFB, San Antonio, Texas

Alternative Description Criterion	Alternative 1 - No Further Action	Alternative 2 - Monitored Natural Attenuation	Alternative 3 – Source Control	Alternative 4 - Source Ex Situ and In Situ Treatment, Perimeter Control, and Off Base Control
(d) Type and Quantity of Treatment Residual	None	None	A pump and treat system using UV Oxidation would result in the production of innocuous products such as ethene, carbon dioxide, water, and salts. The groundwater treatment system will generate some minor amounts of solid waste which will need to be properly designated and disposed offsite.	Natural attenuation and bioremediation of groundwater generally degrades chlorinated solvents to innocuous products such as ethene, carbon dioxide, water, and biomass, although intermediate breakdown products are possible. A pump and treat system using UV Oxidation would result in the production of innocuous products such as ethene, carbon dioxide, water, and salts. The groundwater treatment system will generate some minor amounts of solid waste which will need to be properly designated and disposed offsite.
(e) Statutory Preference for Treatment as a Principal Element	Preference not met because no treatment included.	Preference not met because no treatment included.	Preference met because alternative includes UV oxidation of CVOCs.	Preference met because alternative includes UV oxidation and in situ biodegradation of CVOCs.
5. Short Term Effectiveness				
(a) Protection of Workers During Remedial Action	There would be no impacts to workers.	There would be no impacts to workers.	No significant impacts to workers from installation and operation would be expected. Standard construction techniques and engineering controls would be used during installation and treatment to ensure minimal worker exposure to VOCs.	No significant impacts to workers from installation or operation of the bioremediation or pump and treat systems. Standard construction techniques and engineering controls would be used during installation and treatment to ensure minimal worker exposure to VOCs. To further protect workers, procedures for the handling of chemicals related to this activity will be developed.
(b) Protection of Community During Remedial Action	There would be no impacts to the community assuming current groundwater use controls remain in place.	There would be no impacts to the community assuming current groundwater use controls remain in place.	No significant impacts on local residents would be expected from the pump and treat operation. Assuming controls remain in place, the public would not be exposed to contaminated groundwater. Activity related to installation of new wells/trenches and construction of the treatment facility would be minimal. Airborne VOC emissions would be in very low concentrations and total quantities.	No significant impacts on local residents would be expected from in situ groundwater bioremediation, or pump and treat operation. Activity related to installation of new wells/trenches and construction of the treatment facility would be minimal. Appropriate controls will be instituted during construction of wells in off-base areas to protect the community. Airborne VOC emissions would be in very low concentrations and total quantities.
(c) Environmental Effects	Further groundwater degradation and migration would be expected.	Further groundwater degradation and migration would be expected.	No adverse environmental effects would be expected. Soil erosion mitigation would be necessary during installation of extraction wells/trenches and groundwater piping. Mitigative actions would protect the environment from adverse construction effects. Treated groundwater would be discharged to a permitted outfall, but contaminant concentrations would be below levels of concern.	No adverse environmental effects would be expected. Soil erosion mitigation would be necessary during excavation and installation of injection wells and piping. Mitigative actions would protect the environment from adverse construction effects. Treated groundwater would be discharged to a permitted outfall, but contaminant concentrations would be below levels of concern.

TABLE 7.1
Detailed Evaluation of Groundwater Alternatives
Kelly AFB, San Antonio, Texas

Alternative Description Criterion	Alternative 1 - No Further Action	Alternative 2 - Monitored Natural Attenuation	Alternative 3 – Source Control	Alternative 4 - Source Ex Situ and In Situ Treatment, Perimeter Control, and Off Base Control
(d) Time Until RAOs Are Achieved	□Contaminants would be present in some areas for as much as 30 years.	□In areas that will remain under DoD control, up to 30 years would be required for the contaminant levels to reach PRGs. Modeling results indicate that Plume D may still be expanding, and may continue to expand for almost 30 years due continuing but very small releases of contaminants from the vadose zone, aquifer sediments or leaky sewer lines. □In areas that are currently under DoD control, but are subject to base closure, as much as 30 years would be required for the contaminant levels to reach PRGs. □In areas not currently under DoD control, it would take almost 30 years for contamination levels to reach PRGs as the on base contamination gradually moves further off base and attenuates.	□Migration of groundwater contamination would be controlled immediately upon startup of the pumping system. □In areas that will remain under DoD controlup to 22 years would be required for the contaminant levels to reach PRGs. □In areas that are currently under DoD control, but subject to base closure, 23 years would be required for the contaminant levels to reach PRGs. □In areas not currently under DoD control, almost 30 years would be required for the contaminant levels to reach PRGs.	□Migration of groundwater contamination from source areas and the base perimeter would be controlled immediately upon startup of the pumping system. □For source areas remediated by in situ bioremediation, reduction of groundwater contamination will start immediately, but the rate of contaminant mass reduction will increase over time as the biological organisms grow. □ In areas that will remain under DoD control, up to 22 years would be required for the contaminant levels to reach PRGs. □In areas that are currently under DoD control, but subject to base closure, 23 years would be required for the contaminant levels to reach PRGs. □In areas not currently under DoD control up to 21 years would be required for the contaminant levels to reach PRGs.
6. Implementability				
(a) Technical Feasibility	□Natural attenuation is known to occur. Estimates of the rate of degradation are highly uncertain. Without monitoring, it would be difficult to determine when the groundwater contamination concentrations are within acceptable risk levels.	□Natural attenuation is known to occur. Estimates of the rate of degradation are highly uncertain. Monitoring would be used to determine when the groundwater contamination concentrations are within acceptable risk levels.	□Natural attenuation is known to occur. Groundwater extraction is a proven method for hydraulic gradient control although the heterogeneous nature of the aquifer may affect the implementability. UV oxidation is a common treatment method for VOC contaminated groundwater.	□Groundwater extraction is a proven method for hydraulic gradient control although the heterogeneous nature of the aquifer may affect the implementability. UV oxidation is a common treatment method for VOC contaminated groundwater. In situ bioremediation of groundwater is a relatively new technology. The heterogeneous nature of the aquifer may also affect the implementability of in situ bioremediation.
(b) Administrative Feasibility	□No administrative problems affecting implementability would be expected. An indefinite period of institutional control would be required.	□No administrative problems affecting implementability would be expected. A period of institutional control lasting more than 40 years would be required.	□No significant administrative problems affecting implementability are expected for construction of wells and trenches on-base.	□No significant administrative problems affecting implementability are expected. A permit for injection of an organic substrate or an electron acceptor would be needed for in situ bioremediation of the groundwater. For the pump and treat system, permits and easements from the local municipality would be required for off-base well construction and pipeline installation.
(c) Availability of Services and Materials	□No services necessary.	□No services necessary.	□Services and materials for construction of the pump and treat system are readily available.	□Services and materials for construction of both the bioremediation, and pump and treat systems are readily available.
7. Cost ($ 000), 1998 Dollars (rounded)	Direct Capital Cost $0 O & M Present Worth $0 Total Present Worth $0	Direct Capital Cost $0 O & M Present Worth $1,590 Total Present Worth $1,590	Direct Capital Cost $2,520 O & M Present Worth $4,840 Total Present Worth $7,360	Direct Capital Cost $4,730 O & M Present Worth $6,210 Total Present Worth $10,900

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TABLE 7.1
Detailed Evaluation of Groundwater Alternatives
Kelly AFB, San Antonio, Texas

Alternative Description Criterion	Alternative 5 - Source and Perimeter Control	Alternative 6 - Targeted Source and Perimeter Control	Alternative 7 - Source Ex Situ and In Situ Treatment and Perimeter Control	Alternative 8-In Situ Oxygen Treatment For Plume A Source and In Situ Treatment at Perimeter	Alternative 9- Insitu Bioremedation at Plume Source and Perimeter Control
1. Overall Protection of Human Health and the Environment (See Note 1)	Pump and treat would control further contaminant migration from the source areas. Natural attenuation would ultimately reduce the mass of contamination, however, and the time required would be almost 30 years.	Pump and treat would control further contaminant migration from the source areas. Natural attenuation would ultimately reduce the mass of contamination, however, and the time would be almost 30 years.	Bioremediation, and pump and treat, of the groundwater would reduce or eliminate contamination and future off-site migration. Natural attenuation would ultimately reduce the mass of contamination, however, the time required would be almost 30 years	Protective of human health and theenvironment. The groundwater is currently not being used, so there is no current risk from groundwater consumption. Institutional control are planned and should prevent future consumption of the groundwater.	Protective of human health and theenvironment. The groundwater is currently not being used, so there is no current risk from groundwater consumption. Institutional control are planned and should prevent future consumption of the groundwater..
2. Compliance with ARARs (See Note 2)	Waste generated during drilling/trenching activities would be designated and disposed as appropriate. Treated groundwater would meet discharge permit concentration limits. Off-gas (if any) from the treatment of groundwater would meet state standards for a permit exemption. Solid waste generated from the groundwater treatment systems would be designated and disposed as appropriate.	Waste generated during drilling/trenching activities would be designated and disposed as appropriate. Treated groundwater would meet discharge permit concentration limits. Off-gas (if any) from the treatment of groundwater would meet state standards for a permit exemption. Solid waste generated from the groundwater treatment systems would be designated and disposed as appropriate.	A permit for injection of an organic substrate or an electron acceptor would be needed for in situ bioremediation of the groundwater. Treated groundwater would meet discharge permit concentration limits. Off-gas (if any) from the treatment of groundwater would meet state standards for a permit exemption. Solid waste generated from the groundwater treatment systems would be designated and disposed as appropriate. Waste generated during all drilling/trenching activities would be designated and disposed as appropriate.	A permit for injection of chemicals into the aquifer would be needed for in situ oxygen treatment of the groundwater. Waste generated during drilling activities would be designated and disposed as appropriate.	A permit for injection of chemicals into the aquifer would be needed for in situ oxygen treatment of the groundwater. Waste generated during drilling activities would be designated and disposed as appropriate.
3. Long-Term Effectiveness and Permanence					
(a) Magnitude of Residual Risks	Groundwater contaminant concentrations would be reduced to below PRGs.	Groundwater contaminant concentrations would be reduced to below PRGs.	Groundwater contaminant concentrations would be reduced to below PRGs.	Greater uncertainty about the ability to achieve groundwater clean-up standards due to unknown effectiveness of the oxidation process, uncertainty in the ability to deliver the chemicals to the contaminated zones, and potential for other sources.	There is some uncertainty about the ability to achieve groundwater clean-up standards due to unknown biodegradation rates, uncertainty in the ability to deliver the electron donor to the contaminated zones, and the potential for other sources to provide contaminant flux to the treatment area.

TABLE 7.1
Detailed Evaluation of Groundwater Alternatives
Kelly AFB, San Antonio, Texas

Alternative Description Criterion	Alternative 5 - Source and Perimeter Control	Alternative 6 - Targeted Source and Perimeter Control	Alternative 7 - Source Ex Situ and In Situ Treatment and Perimeter Control	Alternative 8-In Situ Oxygen Treatment For Plume A Source and In Situ Treatment at Perimeter	Alternative 9- Insitu Bioremedation at Plume Source and Perimeter Control
(b) Adequacy and Reliability of Controls	Institutional controls preventing use of shallow groundwater in on base areas would be most reliable because of the continuing DoD control of the area. Institutional controls preventing use of shallow groundwater in off base areas would be least effective because of the many land owners involved and the difficulty in assuring land owners are in compliance with the controls. Nevertheless, existing institutional controls have generally been reliable in preventing use of shallow groundwater and are expected to continue to be so. This alternative would adequately control further migration of contaminants as long as the pump and treat systems are operated until natural attenuation diminishes the groundwater contamination to acceptable levels.	Institutional controls preventing use of shallow groundwater in on base areas would be most reliable because of the continuing DoD control of the area. Institutional controls preventing use of shallow groundwater in off base areas would be least effective because of the many land owners involved and the difficulty in assuring land owners are in compliance with the controls. Nevertheless, existing institutional controls have generally been reliable in preventing use of shallow groundwater and are expected to continue to be so. This alternative would adequately control further migration of contaminants as long as the pump and treat systems are operated until natural attenuation diminishes the groundwater contamination to acceptable levels.	Institutional controls preventing use of shallow groundwater in on base areas would be most reliable because of the continuing DoD control of the area. Institutional controls preventing use of shallow groundwater in off base areas would be least effective because of the many land owners involved and the difficulty in assuring land owners are in compliance with the controls. Nevertheless, existing institutional controls have generally been reliable in preventing use of shallow groundwater and are expected to continue to be so. This alternative would adequately control further migration of contaminants as long as the aquifer is actively bioremediated and contaminated groundwater is extracted and treated.	Less reliable because in situ oxidation is relatively new to the industry, so it is not clear how reliable it will be. The consequences of the system failing are relatively minor (should not cause harm), unless failure results in release of the oxidizing compounds into the environment.	Less reliable because enhancement of microorganisms is relatively new to the industry, so it is not clear how reliable it will be.
4. Reduction of TMV Through Treatment					
(a) Trea7tment Processes Used	Groundwater will be extracted and treated by UV oxidation.	Groundwater will be extracted and treated by UV oxidation.	Groundwater will be bioremediated in place, or extracted and treated by UV oxidation.	Less effective in reducing toxicity, mobility, and volume because contaminants will be degraded in the areas influenced by the injected potassium permanganate; however, due to heterogeneous geology, some areas may not be influenced.	Less effective in reducing toxicity, mobility, and volume because contaminants will be degraded in the areas influenced by the injected vegetable oil; however, due to heterogeneous geology, some areas may not be influenced.
(b) Degree and Quantity of TMV Reduction	Total Estimated Mass removed over the life of the alternative: 480 lbs:	Total Estimated Mass removed over the life of the alternative: 440 lbs:	Total Estimated Mass removed over the life of the alternative: 480 lbs:		

TABLE 7.1
Detailed Evaluation of Groundwater Alternatives
Kelly AFB, San Antonio, Texas

Alternative Description Criterion	Alternative 5 - Source and Perimeter Control	Alternative 6 - Targeted Source and Perimeter Control	Alternative 7 - Source Ex Situ and In Situ Treatment and Perimeter Control	Alternative 8-In Situ Oxygen Treatment For Plume A Source and In Situ Treatment at Perimeter	Alternative 9- Insitu Bioremedation at Plume Source and Perimeter Control
(c) Irreversibility of TMV Reduction	Natural attenuation and ex situ treatment of VOCs are irreversible.	Natural attenuation and ex situ treatment of VOCs are irreversible.	Natural attenuation, ex situ treatment, and in situ bioremediation of VOCs are irreversible.	In situ bioremediation of VOCs are irreversible.	In situ bioremediation of VOCs are irreversible
(d) Type and Quantity of Treatment Residual	A pump and treat system using UV Oxidation would result in the production of innocuous products such as ethene, carbon dioxide, water, and salts. The groundwater treatment system will generate some minor amounts of solid waste which will need to be properly designated and disposed offsite.	A pump and treat system using UV Oxidation would result in the production of innocuous products such as ethene, carbon dioxide, water, and salts. The groundwater treatment system will generate some minor amounts of solid waste which will need to be properly designated and disposed offsite.	Natural attenuation and bioremediation of groundwater generally degrades chlorinated solvents to innocuous products such as ethene, carbon dioxide, water, and biomass, although intermediate breakdown products are possible. A pump and treat system using UV Oxidation would result in the production of innocuous products such as ethene, carbon dioxide, water, and salts. The groundwater treatment system will generate some minor amounts of solid waste which will need to be properly designated and disposed offsite.	Natural attenuation and bioremediation of groundwater generally degrades chlorinated solvents to innocuous products such as ethene, carbon dioxide, water, and biomass, although intermediate breakdown products are possible.	Natural attenuation and bioremediation of groundwater generally degrades chlorinated solvents to innocuous products such as ethene, carbon dioxide, water, and biomass, although intermediate breakdown products are possible.
(e) Statutory Preference for Treatment as a Principal Element	Preference met because alternative includes UV oxidation of CVOCs.	Preference met because alternative includes UV oxidation of CVOCs.	Preference met because alternative includes UV oxidation and in situ biodegradation of CVOCs.	Preference met because alternative includes in situ biodegradation of CVOCs.	Preference met because alternative includes in situ biodegradation of CVOCs
5. Short Term Effectiveness					
(a) Protection of Workers During Remedial Action	No significant impacts to workers from installation and operation would be expected. Standard construction techniques and engineering controls would be used during installation and treatment to ensure minimal worker exposure to VOCs.	No significant impacts to workers from installation and operation would be expected. Standard construction techniques and engineering controls would be used during installation and treatment to ensure minimal worker exposure to VOCs.	No significant impacts to workers from installation or operation of the bioremediation or pump and treat systems. Standard construction techniques and engineering controls would be used during installation and treatment to ensure minimal worker exposure to VOCs. To further protect workers, procedures for the handling of chemicals related to this activity will be developed.	More risk during implementation because handling oxidizing agents creates risk of release and some drilling fluids may reach the surface during construction; however, quantities are not expected to be large.	Less risk during implementation because limited construction wastes (groundwater, soil, drilling fluids, and pavement) expected. Some drilling fluids may reach the surface during construction, however, quantities are not expected to be large.

TABLE 7.1
Detailed Evaluation of Groundwater Alternatives
Kelly AFB, San Antonio, Texas

Alternative Description Criterion	Alternative 5 - Source and Perimeter Control	Alternative 6 - Targeted Source and Perimeter Control	Alternative 7 - Source Ex Situ and In Situ Treatment and Perimeter Control	Alternative 8-In Situ Oxygen Treatment For Plume A Source and In Situ Treatment at Perimeter	Alternative 9- Insitu Bioremedation at Plume Source and Perimeter Control
(b) Protection of Community During Remedial Action	No significant impacts on local residents would be expected from the pump and treat operation. Assuming controls remain in place, the public would not be exposed to contaminated groundwater. Activity related to installation of new wells/trenches and construction of the treatment facility would be minimal. Airborne VOC emissions would be in very low concentrations and total quantities.	No significant impacts on local residents would be expected from the pump and treat operation. Assuming controls remain in place, the public would not be exposed to contaminated groundwater. Activity related to installation of new wells/trenches and construction of the treatment facility would be minimal. Airborne VOC emissions would be in very low concentrations and total quantities.	No significant impacts on local residents would be expected from in situ groundwater bioremediation, or pump and treat operation. Activity related to installation of new wells/trenches and construction of the treatment facility would be minimal. Airborne VOC emissions would be in very low concentrations and total quantities.	No significant impacts on local residents would be expected from in situ groundwater bioremediation. Activity related to installation of new wells/trenches and construction of the treatment facility would be minimal. Airborne VOC emissions would be in very low concentrations and total quantities.	No significant impacts on local residents would be expected from in situ groundwater bioremediation. Activity related to installation of new wells/trenches and construction of the treatment facility would be minimal. Airborne VOC emissions would be in very low concentrations and total quantities.
(c) Environmental Effects	No adverse environmental effects would be expected. Soil erosion mitigation would be necessary during installation of extraction wells/trenches and groundwater piping. Mitigative actions would protect the environment from adverse construction effects. Treated groundwater would be discharged to a permitted outfall, but contaminant concentrations would be below levels of concern.	No adverse environmental effects would be expected. Soil erosion mitigation would be necessary during installation of extraction wells/trenches and groundwater piping. Mitigative actions would protect the environment from adverse construction effects. Treated groundwater would be discharged to a permitted outfall, but contaminant concentrations would be below levels of concern.	No adverse environmental effects would be expected. Soil erosion mitigation would be necessary during excavation and installation of injection wells and piping. Mitigative actions would protect the environment from adverse construction effects. Treated groundwater would be discharged to a permitted outfall, but contaminant concentrations would be below levels of concern.	No adverse environmental effects would be expected. Soil erosion mitigation would be necessary during excavation and installation of injection wells and piping. Mitigative actions would protect the environment from adverse construction effects.	No adverse environmental effects would be expected. Soil erosion mitigation would be necessary during excavation and installation of injection wells and piping. Mitigative actions would protect the environment from adverse construction effects.

TABLE 7.1
Detailed Evaluation of Groundwater Alternatives
Kelly AFB, San Antonio, Texas

Alternative Description Criterion	Alternative 5 - Source and Perimeter Control	Alternative 6 - Targeted Source and Perimeter Control	Alternative 7 - Source Ex Situ and In Situ Treatment and Perimeter Control	Alternative 8-In Situ Oxygen Treatment For Plume A Source and In Situ Treatment at Perimeter	Alternative 9- Insitu Bioremedation at Plume Source and Perimeter Control
(d) Time Until RAOs Are Achieved	□Migration of groundwater contamination from source areas would be controlled immediately upon startup of the pumping system. □ In areas that will remain under DoD control, about 22 years would be required for the contaminant levels to reach PRGs. □In areas that are currently under DoD control, but subject to base closure, up to 23 years would be required for the contaminant levels to reach PRGs. □In areas not currently under DoD control, up to 21 years would be required for the contaminant levels to reach PRGs..	□Migration of groundwater contamination from source areas and the base perimeter would be controlled immediately upon startup of the pumping system. □In areas that will remain under DoD control, about 22 years would be required for the contaminant levels to reach PRGs. □In areas that are currently under DoD control, but subject to base closure, about 22 years would be required for the contaminant levels to reach PRGs. □In areas not currently under DoD control, up to 21 years would be required for the contaminant levels to reach PRGs.	□Migration of groundwater contamination from source areas and the base perimeter would be controlled immediately upon startup of the pumping system. □For source areas remediated by in situ bioremediation, reduction of groundwater contamination will start immediately, but the rate of contaminant mass reduction will increase over time as the biological organisms grow. □In areas that will remain under DoD control, about 22 years would be required for the contaminant levels to reach PRGs. □In areas that are currently under DoD control, but subject to base closure, up to 23 years would be required for the contaminant levels to reach PRGs. □In areas not currently under DoD control, up to 21 years would be required for the contaminant levels to reach PRGs.	For source areas remediated by in situ bioremediation, reduction of groundwater contamination will start immediately, but the rate of contaminant mass reduction will increase over time as the biological organisms grow.	For source areas remediated by in situ bioremediation, reduction of groundwater contamination will start immediately, but the rate of contaminant mass reduction will increase over time as the biological organisms grow.
6. Implementability					

TABLE 7.1
Detailed Evaluation of Groundwater Alternatives
Kelly AFB, San Antonio, Texas

Alternative Description Criterion	Alternative 5 - Source and Perimeter Control	Alternative 6 - Targeted Source and Perimeter Control	Alternative 7 - Source Ex Situ and In Situ Treatment and Perimeter Control	Alternative 8-In Situ Oxygen Treatment For Plume A Source and In Situ Treatment at Perimeter	Alternative 9- Insitu Bioremedation at Plume Source and Perimeter Control
(a) Technical Feasibility	Natural attenuation is known to occur. Groundwater extraction is a proven method for hydraulic gradient control although the heterogeneous nature of the aquifer may affect the implementability. UV oxidation is a common treatment method for VOC contaminated groundwater.	Natural attenuation is known to occur. Groundwater extraction is a proven method for hydraulic gradient control although the heterogeneous nature of the aquifer may affect the implementability. UV oxidation is a common treatment method for VOC contaminated groundwater.	Natural attenuation is known to occur. Groundwater extraction is a proven method for hydraulic gradient control although the heterogeneous nature of the aquifer may affect the implementability. UV oxidation is a common treatment method for VOC contaminated groundwater. In situ bioremediation of groundwater is a relatively new technology. The heterogeneous nature of the aquifer may also affect the implementability of in situ bioremediation.	This alternative may be difficult to implement because the construction equipment will cause noise and dust, drilling could disrupt utilities, and handling oxidizing chemicals could be challenging.	This alternative may be difficult to implement because the construction equipment will cause noise and dust and drilling could disrupt utilities.
(b) Administrative Feasibility	No significant administrative problems affecting implementability are expected for construction of wells and trenches on-base.	No significant administrative problems affecting implementability are expected for construction of wells and trenches on-base.	No significant administrative problems affecting implementability are expected. A permit for injection of an organic substrate or an electron acceptor would be needed for in situ bioremediation of the groundwater.	No significant administrative problems affecting implementability are expected. A permit for injection of an organic substrate or an electron acceptor would be needed for in situ bioremediation of the groundwater.	No significant administrative problems affecting implementability are expected. A permit for injection of an organic substrate or an electron acceptor would be needed for in situ bioremediation of the groundwater.
(c) Availability of Services and Materials	Services and materials for construction of the pump and treat system are readily available.	Services and materials for construction of the pump and treat system are readily available.	Services and materials for construction of both the bioremediation, and pump and treat systems are readily available.	Services and materials for construction of both the bioremediation, and pump and treat systems are readily available.	Services and materials for construction of both the bioremediation, and pump and treat systems are readily available.
7. Cost ($ 000), 1998 Dollars (rounded)	Direct Capital Cost O & M Present Worth Total Present Worth	Direct Capital Cost O & M Present Worth Total Present Worth	Direct Capital Cost O & M Present Worth Total Present Worth	Direct Capital Cost O & M Present Worth Total Present Worth	Direct Capital Cost $3,420 O & M Present Worth $230 Total Present Worth $4,360

Notes:
Alternatives 8 and 9 address Plume A, other plumes are addressed in Alternatives 1 through 7.

ARAR	Applicable or relevant and appropriate requirement
PRG	Preliminary remediation goal
discharge permit	National Pollutant Discharge Elimination System
VOC	Volatile organic compound

1. Assuming existing controls continue, all alternatives would protect human health because there is no current or proposed future use of the groundwater. However, an unacceptable risk could occur if the groundwater were consumed, as long as contaminant concentrations remain above PRGs.
2. For a detailed listing and analysis of key ARARs, see Section 4.2.

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TABLE 7.2
Summary of Costs for Zone 5 Groundwater Alternatives
Kelly AFB, San Antonio, Texas

Alternative	Description	Capital Costs ($ 000)	O&M Present Worth ($ 000)	Total Project Present Worth ($ 000)
Alternative 1	No Further Action	0	0	0
Alternative 2	Monitored Natural Attenuation	0	1,590	1,590
Alternative 3	Source Control	2,520	4,840	7,360
Alternative 4	Source Ex Situ and In Situ Treatment, Perimeter Control, and Off Base Control	4280	6,000	10,250
Alternative 5	Source and Perimeter Control	2,500	4900	7,400
Alternative 6	Targeted Source and Perimeter Control	2,230	4,700	6,940
Alternative 7	Source Ex Situ and In Situ Treatment and Perimeter Control	2,990	5,550	8,500
Alternative 8	In Situ Oxygen Treatment for Plume A Source and In Situ Perimeter Control	5,460	630	8,040
Alternative 9	In Situ Bioremediation Treatment for Plume A Source and In Situ Perimeter Control	3,420	230	4,360

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SECTION 8.0

Recommended Alternatives

This section presents alternatives recommended for final action to address groundwater contamination in Zone 5.

Based on the detailed evaluation and comparative analysis of alternatives, Alternative 7, source and perimeter control, is recommended for groundwater remediation for all plumes except Plume A. The recommended alternative for Plume A is Alternative 9. Alternatives 7 and 9 will effectively reduce the overall risk to human health and the environment via the following:

- Instituting administrative controls (deed restrictions) and preventing use of groundwater containing contaminants at concentrations that exceed cleanup goals (contaminant concentrations that exceed MCLs or MSCs, as applicable) in areas currently held by the base.
- Reducing or preventing further migration of contaminated groundwater from areas that will remain on base and under Air Force control to areas that will be off base, after base closure.
- Restoring offbase and onbase groundwater to MCLs or MSCs within a reasonable timeframe

Alternative 1 (No Further Action) and Alternative 2 (Monitored Natural Attenuation) would not effectively reduce or prevent further migration contaminated groundwater from on base areas to off base areas and would not restore groundwater to MCLs or MSCs within a reasonable timeframe because they do no active remediation of any of the plumes. This alternative would be readily implementable, would comply with ARARs, would be effective both in the long-term and short-term, and would effectively reduce TMV through extraction and treatment of groundwater exceeding MCL/MSC limits.

Alternative 3 (source control) would not effectively prevent further migration of contaminated groundwater from onbase areas to offbase areas because it does not include the perimeter collection system for Plume A. Alternative 4 (source ex situ treatment and in situ treatment, perimeter control, and offbase control) would achieve essentially no increase in the level of groundwater remediation, but at a cost almost 50 percent higher than Alternative 7. Alternative 5 would achieve the same degree of groundwater remediation as Alternative 7, but effective pump and treat will be limited by the nature of the shallow groundwater in the area and the implementation of pipeline systems. Also, the effectiveness of in-situ treatment with Alternative 4 (and Alternative 7) is less certain because of aquifer heterogeneities and the relatively poor biodegradability of the CVOCs. Alternative 6 (targeted source and perimeter control) would not effectively prevent further migration of contaminated groundwater from onbase areas to offbase areas. Alternative 8 is more costly than Alternative 9 and does not provide any more protection than Alternative 9.

The cost for Alternative 5 is approximately $ 7,960,000 and the cost for Alternative 9 is $4,360,000.

The following sections discuss the recommended remediation approach for each plume.

8.1 Plume A – On- and Offbase TCE

On the basis of the detailed analysis of alternatives, in-situ bioremediation of groundwater at the Plume A source area with PRB along the base perimeter, is the recommended alternative for Plume A (Alternative 9). This alternative should effectively reduce the overall risk to human health and the environment from the source and is lowest in cost to implement. This alternative would comply with the ARARs, and there are no NEPA-related issues. There are some implementability issues associated with this alternative, but all of the other alternatives have similar implementability issues associated with the heterogeneous nature of the vadose zone and shallow aquifer. Additionally, more characterization data are needed for remedial design, but again, all of the alternatives require some further characterization.

The cost for remediation of Plume A is approximately $4,360,000 based on selection of Alternative 9.

8.2 Plume C – Chlorobenzene and Arsenic

An interim remediation measure (groundwater extraction and treatment) is ongoing. An additional interim measure was recently performed and included excavation of contaminated soil in the sump area and dual-phase groundwater and vapor extraction within the groundwater plume area. The interim groundwater treatment system is having a positive effect on plume reduction and continued operation of this system is recommended. Further actions addressing this groundwater plume are not necessary. No additional remediation measures are proposed for Plume C.

8.3 Plume D – 1600 Area – TCE, PCE, and 1, 2-DCE Plume

Plume D is a combination of at least four smaller contaminant plumes that do not necessarily have the same source. These plumes are located in an area slated for transfer to civilian control, and as such require remediation to restore the groundwater to MCLs or MSCs within a reasonable timeframe.

The recommended alternative for Plume D is to install enhanced bioremediation systems at source areas. Modeling indicates that the alternative will effectively control migration from source areas. Existing extractions systems down gradient of sources can prevent migration of disperse contaminant plumes.

The cost for remediation of Plume D is approximately $570,000. This cost represents a reduction of about $232,000 from the Alternative 5 estimate for Plume D for elimination of the base perimeter extraction system.

8.4 Plume F – Low Concentration PCE/TCE

Plume F is a combination of at least four smaller contaminant plumes that do not necessarily have the same source. The maximum concentration of contaminants is not significantly above MCLs, and modeling indicates that monitored natural attenuation will adequately reduce contamination levels within a reasonable timeframe (approximately 15 to 20 years).

The cost for remediation of Plume F is approximately $207,000. This cost represents a reduction of about $332,000 from the Alternative 5 estimate for Plume F for elimination of the plume perimeter extraction system.

8.5 Plume H – Central Runway – TCE, Total 1,2-DCE

Plume H is in a part of Zone 5 that will be reassigned to Lackland AFB and therefore will remain under Air Force control. Modeling results indicate that without further source loading, TCE concentrations should decline below MCLs before reaching the base boundary. Contaminant concentrations are relatively low and monitored natural attenuation should adequately reduce contamination levels within about 7 years. If TCE concentrations do not decline sufficiently through monitored natural attenuation, then the existing Zone 1 recovery and treatment system (D-4) will intercept the plume. It is estimated that it will take approximately 10 years for any remaining contamination from Plume H to reach the Zone 1 recovery systems. Kelly AFB estimates that the existing Zone 1 recovery systems will be operating for the next 25 to 30 years, which will be adequate to recover the contaminated groundwater if necessary.

The cost for monitoring Plume H is approximately $71,500. This is the same cost estimate for Plume H remediation under Alternative 5.

8.6 Plume J – KY028 (1100 Area) – PCE, TCE

Plume J is migrating southwest. Contaminant concentrations are low enough that MNA will adequately reduce levels of contamination for Plume J.

The cost for monitoring Plume J is approximately $223,000. This is the same cost estimate for Plume J remediation under Alternative 5.

8.7 Plume K – West – Chlorobenzene

Plume K is in a part of Zone 5 that will be reassigned to Lackland AFB and therefore will remain under Air Force control. A study (PES 1998) of monitored natural attenuation at Site SS003 (S-1) indicated that CB is degrading under aerobic aquifer conditions which exist at the perimeter of Plume C. Based on results of the cited study results, CB concentrations in Plume K should also decline below MCLs within a reasonable timeframe before reaching the base boundary. Therefore, monitored natural attenuation will adequately reduce the levels of contamination for Plume K.

The cost for monitoring Plume K is approximately $93,000. This is the same cost estimate for Plume K remediation under Alternative 5.

8.8 Summary of Recommended Alternative

In summary, the recommended groundwater remediation alternative includes the following elements:

- In situ treatment of groundwater in the areas of greatest concentration for Plume D.
- Perimeter collection of groundwater for Plumes D, F, and H.
- Insitu treatment of groundwater at Plume A.
- Insitu treatment of groundwater at the perimeter for Plume A.
- Monitored natural attenuation for Plumes J and K and the offbase portion of Plume A.

The cost for implementing the recommended alternatives is approximately $9,884,000 (($5,524,00 for Alternative 5 and $4,360,000 for Alternative 9). This total includes approximately $4,498,000 for construction, O&M of a new treatment plant, with a capacity of 74 gpm (a reduction of $379,000 from the Alternative 5 cost), plus the cost for remediating or monitoring each individual plume, as described in sections 8.1 through 8.10.

SECTION 9.0

Evaluation of Plume B

9.1 Background for Plume B

Based on its review and analysis of the groundwater and soil data collected by former Kelly AFB and its contractors, Mitretek (2000) suggested that the three former Kelly AFB sources examined cannot be the source of the high (>1,000µg/L) PCE concentrations found in off-base Monitor Well SS050MW156. The higher concentrations reported for this well are about 1 to 2 percent of the PCE solubility limit and may suggest that the potential source area is nearby and is likely to contain DNAPL. Using the groundwater CVOC contamination patterns and source locations at Kelly AFB as a model, the potential off-base PCE source area can be expected to be within 1,200 feet of Monitor Well SS050MW156. The industrial and commercial operations—potential sources just upgradient (west) of this well—include aircraft engine maintenance and repair, welding, machine shops, and documented use of hazardous substances. These operations have been present since the early 1950s and are the type of operations that have historically used CVOCs. However, this does not preclude roadside disposal by other parties that are not affiliated with this area. Based on widely spaced groundwater samples, Plume B extends for several miles to the east and southeast, where it comingles with CVOC plumes from Kelly AFB near the east side of East Kelly and a CVOC plume originating just north of East Kelly.

At Site S-1, the dominant groundwater contaminants are benzene and chlorobenzenes with low (<25 µg/L) levels of TCE and PCE. Contaminants in Monitor Well SS050MW156 could not originate at Site S-1 because the well is not on the flow path from Site S-1. The plume from Site S-1 clearly trends north and east of East Kelly away from Monitor Well SS050MW156, and none of the PCE concentrations at Site S-1 come close to approaching the levels seen at SS050MW156.

The dominant groundwater contaminant at Site IS-1 is TCE and its degradation product 1,2 DCE, with concentrations of several hundred micrograms per liter common near the potential source area. PCE is occasionally present, but the concentrations in groundwater have always been low (<20 µg/L). A soil boring drilled in 1989 (Boring B4-A) contained 143 mg/kg PCE in a saturated soil sample analyzed by a reliable GC/MS method, but none of the soil and groundwater samples collected to date, including a sample taken from this boring shortly after its drilling, support the reported PCE concentration. Three closely spaced borings were drilled in December 1999 to assess the results from Boring B-4A; one boring contained two feet of groundwater with several hundred micrograms per liter of TCE and 1,2 DCE, but no PCE. While two of the borings were dry, a soil sample from just above the top of the Navarro Formation in one of these borings contained TCE at 35.3 µg/kg, but no other VOCs.

A small portion of the TCE plume originating at Site IS-1 may migrate north and move towards Monitor Well SS050MW156. The vast majority of the plume, however, moves south to southeast and does not approach Monitor Well SS050MW156. The TCE and 1,2 DCE in

groundwater near SS050MW156 are much lower than at Site IS-1 and are likely be related to degradation of the off-base PCE rather than Site IS-1. This conclusion is supported by the recent patterns of PCE, TCE, and 1,2 DCE in monitor wells at Site IS-1 and in monitor wells in the upgradient end of Plume B.

The 1500 Area is a 1990 fuel spill, and the fuel release did not contain TCE or PCE. The fuel spill plume is small and localized. The trace amounts of TCE and PCE found in samples from near the 1500 Area are likely to be related to upgradient Site IS-1.

Two of the three Kelly AFB source areas (Sites IS-1 and S-1) contain low levels of PCE, but the concentrations in and immediately downgradient of these two areas are *orders of magnitude lower* than those found in Plume B. Former Kelly AFB does not appear to be the source of the PCE in the off-base plume. The source of this PCE plume is likely to be north of the base boundary within the area identified in Figure 9-1. Former Kelly AFB has developed a remedy for Plume B, with implementation pending the outcome of the TNRCC review of the Mitretek technical report.

The Air Force does not intend to perform remedial actions on Plume B. Kelly AFB has submitted the following report, *Physical and Chemical Characteristics of the Shallow Groundwater Zone and Sources of Groundwater Contamination in the Vicinity of Kelly Air Force Base, Texas, Volume I: Analysis and Recommendations & Volume 2: Aerial Photographs and Related Correspondence and Plates (Mitretek Systems, February 2000),* and, addressing EPA comments, *Physical and Chemical Characteristics of the Shallow Groundwater Zone and Sources of Groundwater Contamination in the Vicinity of Kelly Air Force Base, Texas, Addendum (Mitretek Systems, May 2001).*

9.2 Detailed Evaluation of Alternatives

The following three alternatives will be evaluated as potential remedial methods for treating contaminated groundwater for Plume B. Because the source of the contamination is not located on former Kelly AFB and the nature and location of the source is not known, groundwater remedies are limited to plume management downgradient of the source for Plume B.

- Alternative 1 – **No action**
- Alternative 2– **Monitored Natural Attenuation.**
- Alternative 3– **PRB near source area.**

These three alternatives were evaluated in detail using the following CERCLA criteria:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness

- Implementability
- Cost

Two final criteria, state and community acceptance will be assessed at the conclusion of the public comment period.

In addition, because this document also serves to satisfy former Kelly AFB's obligations under NEPA, the detailed analysis considers potential environmental impacts that are not otherwise addressed by the CERCLA criteria.

The detailed evaluation is presented in **Table 9.1**.

9.3 Comparative Evaluation for Plume B

9.3.1 Overall Protection of Human Health and Environment

Protection of human health and the environment is the basis for the RAOs as well as a "threshold" evaluation criterion (that is, the alternative must be protective in order to be considered for selection.) The primary RAO in evaluating Plume B is to reduce or eliminate further migration of contaminants, thus preventing further degradation of the downgradient groundwater.

Alternative 1 does not achieve the objective of substantially reducing or eliminating further migration of contaminants through the groundwater. Alternative 1 will not be selected and is only being used to compare against alternatives 2 and 3. Alternative 2 will not substantially reduce the migration of contaminants because the source is not controlled. Alternative 3 achieves the objective of substantially reducing or eliminating further migration of contaminants through the groundwater. This alternative would achieve this by intercepting and treating the contaminants in the groundwater associated with Plume B.

9.3.2 Compliance with ARARs

Compliance with ARARs is also a threshold criterion. To be selected, an alternative must meet ARARs. Because former Kelly AFB is not formally subject to CERCLA, the use of the CERCLA waiver process is not appropriate.

9.3.3 Long-Term Effectiveness

The long-term effectiveness of the three alternatives is highly dependent on how well the alternative reduces the residual contamination in the shallow aquifer. Alternative 3 would be effective at reducing the mass of contaminants in the aquifer. This alternative could efficiently treat the affected groundwater.

9.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternatives 2 and 3 all involve in situ treatment to reduce the toxicity, mobility, and volume of contamination in the groundwater with a removal effectiveness of nearly 100 percent.

9.3.5 Short-term Effectiveness

Significant effects on workers, the community, or the environment during remediation would not be expected for any of the alternatives.

Alternative 3 would have the best overall short-term effectiveness because it would eliminate the source of contamination and would allow for cessation of the active groundwater treatment sooner than alternatives 1 and 2.

9.3.6 Implementability

All of the alternatives can be implemented, however, there are technical issues associated with all of the alternatives that involve active remediation alternatives related to the heterogeneous nature of the vadose zone and aquifer. In general, alternatives 2 and 3 involve technologies, services, and materials that are readily available.

9.3.7 Cost

Table 9.1 presents the capital cost present worth for the three alternatives. The lifetime of the alternatives was assumed to be 30 years for the alternatives that actively eliminate the source term or that control or eliminate contamination movement in the groundwater and leave contaminants in the vadose zone.

A detailed cost breakdown of Alternative 1 (No Action) was not included, since no costs would be associated with this alternative. These cost estimates have been developed strictly for comparing the three proposed alternatives. Final project costs will vary from the cost estimates. The final costs of the project and the resulting feasibility will depend on actual labor and material costs, competitive market conditions, actual site conditions, final project scope, the implementation schedule, the firm selected for final engineering design, and other variables. Because of these factors, project feasibility and funding needs must be reviewed carefully before specific financial decisions are made or project budgets are established to help ensure proper project evaluation and adequate funding.

The cost estimates are order-of-magnitude estimates having an intended accuracy range of plus 50 percent to minus 30 percent. The range applies to the alternatives as they are defined in Section 6 and does not account for changes in the scope of the alternatives. Selection of a specific technology or process as the recommended interim remedial alternative is not intended to limit flexibility during remedial design and implementation. It is intended to provide a basis for preparing cost estimates. The specific details of remedial actions and cost estimates for the remedial action would be refined during the design phase.

The cost estimates for Alternatives 1 through 3 range between $0 and $8.04 million.

Alternative 2 is the least costly (within the accuracy of the cost estimates), and Alternative 3 is the most costly alternative.

9.3.8 State Acceptance

State acceptance will be assessed at the conclusion of the public comment period.

9.3.9 Community Acceptance

Community acceptance will be assessed at the conclusion of the public comment period.

9.4 Recommended Alternative for the Plume B

On the basis of the detailed analysis of alternatives presented in Section 9.3, Alternative 3, in-situ PRB downgradient of the suspected source, is the recommended alternative for Plume B. Alternative 3 should effectively reduce the overall risk to human health and the environment from the source and is lowest in cost to implement. Alternative 3 would comply with the ARARs listed in **Tables 3.1** and **3.2**, and there are no NEPA-related issues. There are some implementability issues associated with this alternative, but all of the other alternatives have similar implementability issues associated with the heterogeneous nature of the vadose zone and shallow aquifer. Additionally, more characterization data are needed for remedial design, but again, all of the alternatives require some further characterization.

If during remedial design or remedial action, it becomes apparent that Alternative 3 is not feasible or implementable, due to the nature of the vadose zone and/or aquifer geology or extent of the contamination, a more suitable alternative will need to be selected.

TABLE 9.1
Detailed Evaluation of Alternatives – Plume B
Kelly Air Force Base, Texas

Evaluation Criteria	Alternative 1 No Action	Alternative 2 Monitored Natural Attenuation	Alternative 3 PRB near off base source area
Overall Protection of Human Health and the Environment (See Note 1)	Does not provide protection of human health and the environment.	Protective of human health and the environment: • The groundwater is currently not being used, so there is no current risk from groundwater consumption. Institutional controls are planned and should prevent future consumption of the groundwater.	Protective of human health and the environment: • The groundwater is currently not being used, so there is no current risk from groundwater consumption. Institutional controls are planned and should prevent future consumption of the groundwater.
Compliance with ARARs	Does not comply with ARARs.	Does not apply with TNRCC and EPA MNA Guidance because contaminant source is uncontrolled.	Waste generated during PRB installation activities would be designated and disposed as appropriate.
Long-term Effectiveness			
Magnitude of Residual Risk	Over a long period of time Natural Attenuation processes may achieve groundwater cleanup standards.	Over a long period of time Natural Attenuation processes may achieve groundwater cleanup standards	Technology will permanently destroy contaminants.
Adequacy and Reliability of Controls	NA	Reliable	Less reliable: • The consequences of the system failing are relatively minor (should not cause harm), unless failure results in the accumulation of vinyl chloride.
Reduction of Toxicity, Mobility, and Volume Through Treatment			
	Not effective in reducing toxicity, mobility, and volume.	Because source is not controlled will be less effective in reducing toxicity, mobility, and volume.	Effective in reducing toxicity, mobility, and volume.
Short Term Effectiveness			
	Poor short term effectiveness.	Poor short term effectiveness.	Less risk during implementation: • Limited construction wastes (groundwater, soil, drilling fluids, and pavement) expected. • Some drilling fluids may reach the surface during construction; however, quantities are not expected to be large.
Implementability			
	Easily implementable	Easy to implement.	Difficult to implement: • Construction

Evaluation Criteria	Alternative 1 No Action	Alternative 2 Monitored Natural Attenuation	Alternative 3 PRB near off base source area
			equipment will cause noise and dust. • Installation could disrupt utilities.
Cost ($ 000), 2001 Dollars			
Capital Cost	$0	$0	**$1,993,920**
Operation and Maintenance Cost	$0	$1,219,200	$3,206,400
Total Project Present Worth	$0	$1,219,200	$6,626,400
State Acceptance (See Note 2)			
Community Acceptance (See Note 2)			
Environmental Effects (NEPA)	No adverse environmental effects would be expected.	No adverse environmental effects would be expected.	No adverse environmental effects would be expected. Mitigative actions would protect the environment from adverse construction effects.

1. Assuming existing controls continue, all alternatives would protect human health because there is no current or proposed future use of the groundwater. However, an unacceptable risk could occur if the groundwater were consumed, as long as contaminant concentrations remain above MCLs.

2. Regulatory and Community acceptance will be assessed at the conclusion of the public comment period.

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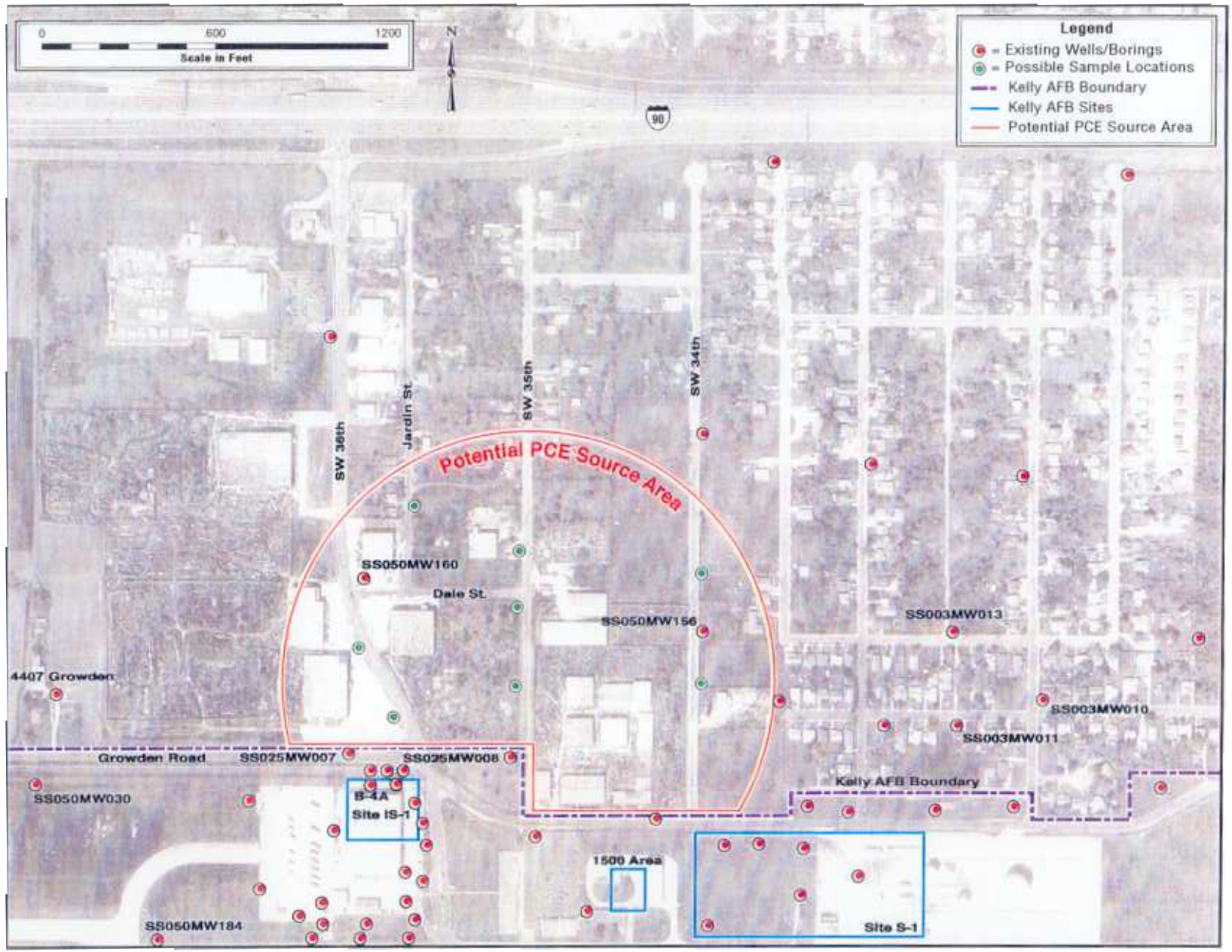

igure 9-1. Possible Sample Locations in the Potential Off-Base Northern PCE Source Area

SECTION 10.0

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Appendix A

Site SS025 (IS-1) Soil and Groundwater Analytical Data Summary

(Includes excerpts from *Remedial Investigation Report, Site IS-1,* Prepared for Kelly AFB, Texas, by Southwestern Laboratories, 1992)

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SwL ENVIRONMENTAL SERVICES

a Division of **SOUTHWESTERN LABORATORIES**

1850 GRANDSTAND DRIVE • SAN ANTONIO, TEXAS 78238-4506
FAX 512/680-3232 512/680-5023

REMEDIAL INVESTIGATION REPORT
SITE IS-1
KELLY AFB, TEXAS

Prepared for:
SA-ALC/EMR Bldg. 306
Kelly AFB, Texas 78241

August 5, 1992
SwL Project No: 59-506-91 (Final Report)

Philip C. Pearce
Staff Geologist

John D. Bryant
UST Remediation Program Manager

Bill Little
Manager, Environmental Services

Prepared by:
SOUTHWESTERN LABORATORIES, INC.
1850 Grandstand Drive
San Antonio, Texas 78238

5.0 ANALYTICAL RESULTS

5.1 SOIL - 1989

The September, 1989 sampling and testing program consisted of analyzing soils from existing grade, two feet and four feet in three of the four borings (B-1A to B-3A). The fourth boring (B-4A) was sampled at intervals of 0, 2, 4, 9, 14, 19 and 24 feet. Each soil sample was analyzed for total petroleum hydrocarbons (TPH) by EPA Method 418.1 and volatile organic compounds (VOCs) by EPA Method 8240. TPH concentrations ranged from non-detectable (detection limit of 1 ppm) to 518 ppm. The only VOCs detected were obtained from boring B-4A at a depth of 24 feet. This depth interval is generally coincident with the water table or the capillary fringe.

The B-4A sample at 24 feet yielded 143.3 ppm of tetrachloroethene, 5.7 ppm of 1,2-dichloroethane, 3.6 ppm of trichloroethene, and 10 ppm of 1,1,2-trichloroethane. The results of the September, 1989 soil testing did not yield detectable levels of VOCs in the unsaturated zone. Therefore, the data does not support the theory that VOCs may have migrated to the water table via surface infiltration at these boring locations. A summary of the analytical results is presented in Table III. The analytical laboratory reports and chain-of-custody records are presented in Appendix C.

A groundwater sample was collected from the open boring of B-4A prior to its plugging. The results of water testing are summarized in Sections 5.3 and 5.4.

5.2 SOIL - 1991

The 1991 sampling program consisted of the collection of soil grab samples at 2.5 feet depth intervals from each of nine (9) borings. Four to six samples from each boring were analyzed for volatile organic compounds (VOCs) by EPA Method 8240, semivolatile organic compounds (SVOCs) by EPA Method 8270, and total petroleum hydrocarbons (TPH) by EPA Method 418.1. The soils were also evaluated for metals content. Total arsenic (As) was tested by Method 206.2, barium (Ba) by Method 200.7, cadmium (Cd) by Method 200.7, chromium (Cr) by Method 200.7, lead (Pb) by Method 239.2, mercury (Hg) by Method 245.1, selenium (Se) by Method 270.2, and silver (Ag) by Method 272.1.

As detailed in Section 3.2, each grab sample was screened in the field with a PID to assist in the selection of samples for the analytical testing program. The uniformly low PID responses did not assist in the identification of samples which may exhibit anomalously high VOC concentrations.

Results of VOC Testing

The most significant result of the analytical testing program is the absence of trichloroethene in all soil samples. Since trichloroethene is the predominant VOC observed in area groundwater, its presence in unsaturated zone soil samples could have been indicative of a source area. The absence of trichloroethene in unsaturated soils indicates that the source area was not identified in this investigation.

Dichloromethane (methylene chloride) and acetone were the only VOCs which were detected in the soil samples. Since dichloromethane and acetone are commonly utilized in analytical laboratories, there is a possibility that the reported levels may be false positive results due to the laboratory environment. A discussion of the reported results for soil samples and internal laboratory QA/QC data is presented below.

Dichloromethane was reported in at least one soil sample from each of the nine (9) borings at concentrations ranging from non-detectable to 6.8 ppm.

Dichloromethane was detected a field QA/QC sample from the April 23, 1991 sampling event. After decontamination of a soil sampler, deionized water was rinsed across the sampler and sampled. Dichloromethune was reported in this sample at a concentration of 10 ppb. Dichloromethane was also reported in two (2) of the laboratory's internal method blanks on April 23, 1991. Dichloromethane was reported at a concentration of 0.5 ppm in a soil blank, and at a concentration of 12 ppb in a water blank.

Dichloromethane was not detected in the 1989 sampling program.

Acetone was reported in ten (10) soil samples from MW-1, MW-2 and MW-3 at concentrations ranging from non-detectable to 1.1 ppm. Acetone was not reported in the internal laboratory method blank for the sample set which included soils from MW-1. Consequently, these data do not support the possibility that the acetone in MW-1 soil test results may have been laboratory induced.

Acetone was present at a concentration of 0.4 ppm for the internal laboratory blank which was run with the MW-2 and MW-3 sample set. Six of the ten soil samples which were reported to contain acetone yielded concentrations equal to or less than the laboratory's internal blank result. Therefore, the possibility that the reported acetone in MW-2 and MW-3 samples is a result of laboratory conditions does exist. Acetone was not detected in the 1989 sampling program.

The laboratory internal method blank analyses indicate that laboratory environmental conditions may have been conducive to false positive test results for dichloromethane and

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The laboratory internal method blank analyses indicate that laboratory environmental conditions may have been conducive to false positive test results for dichloromethane and

acetone. The actual presence or absence of these compounds in the represented soils may be qualified by a more rigorous QA/QC program if necessary.

Results of SVOC Testing

Only one (1) semi-volatile analyte was reported in the analytical testing program. Bis (2-ethyl hexyl) phthalate was reported at concentrations ranging from non-detectable to 2.4 ppm, and was reported in six of the 42 test samples. Bis (2-ethyl hexyl) phthalate was not present in any field QA/QC samples or in the laboratory's internal method blanks. Bis (2-ethyl hexyl) phthalate is commonly used as a plasticizer and has the capacity to leach out of the plastic materials. However, its presence in certain laboratory results can not be qualified by the existing data.

Results of TPH Testing

TPH concentrations ranged from non-detectable to 134 ppm. TPH was not detected in any samples from borings B-1 and B-3, and was detected in only one (1) sample from MW-4. It is important to note that the method detection limit for all tests which were reported as non-detectable was 30 ppm.

Soil from MW-1 at 0.5 feet yielded a TPH of 106 ppm. Soil from MW-2 at 0.5 feet yielded a TPH of 134 ppm. The remaining test results were all less than 87 ppm. No strong correlations of TPH concentration versus depth were apparent based the available data. However, elevated TPH concentrations at MW-1 and MW-2 at 0.5 feet could be the result of the accumulation of surface runoff in vehicle use areas.

Results of Total Metals Testing

Metals are naturally present in soils at various ranges of concentrations depending upon the geological source material, climate, soil horizon and other natural conditions. Any samples with concentrations different than the naturally occurring level may or may not be the result of anthropogenic conditions such as vehicular traffic, municipal or industrial activities.

In the absence of a database regarding the natural background concentrations of the metals which were detected, a literature source was utilized to initiate the assessment of the testing data. The literature-based source is limited in value, since the naturally occurring concentrations presented are based on extremely limited analytical data performed on soils which may have a different geological source than the soils present on the site. The literature source utilized in the initial assessment of data was based on work performed by Shacklette and Boerngen, 1984 and Bowen and Lisk, 1972. The San

Antonio regional data from these publications was summarized in Table 4-1 of NUS Corporation's February 1991 report to KAFB titled "Final Draft Remedial Investigation Report Site S-1", at KAFB.

Since some variability in the naturally occurring concentration values is to be expected in natural systems, NUS 1991 suggested that any test results greater than twice the literature-based natural concentration value be considered an indication of potential anthropogenic influence. This parameter (the literature-based naturally occurring concentration multiplied by 2) was termed by NUS as an indicator value.

The naturally occurring levels and indicator levels reported in the NUS report are presented below:

Metal Analyte	Naturally Occurring Level, mg/kg or ppm	Indicator Value mg/kg or ppm
Arsenic (Ar)	6.5	13
Barium (Ba)	500	1000
Cadmium (Cd)	0.06	0.12
Chromium (Cr)	70	140
Lead (Pb)	15	30
Mercury (Hg)	0.13	0.26
Selenium (Se)	0.3	0.6
Silver (Ag)	0.1	0.2

Based on the data presented above, arsenic, cadmium, chromium, lead and silver were detected in concentrations above naturally occurring levels. None of the lead concentration values exceeded the indicator value of 30 ppm. The results for each of these analytes, comparison to the naturally occurring and indicator values, any observed associations or spatial relations are briefly summarized below.

Arsenic concentrations ranged from non-detectable (ND) to 41.3 ppm, and were above the naturally occurring level of 6.5 ppm in 34 of the 42 total samples analyzed. Eighteen of 42 samples were greater than the indicator level of 13 ppm. A subjective review of the data revealed that chromium concentrations were generally less than the indicator

value of 13 ppm at depths greater than 10 feet. The main exception to this observation includes soils from MW-2. All soils from MW-2, except at 0.5 feet depth, exhibited chromium concentrations greater than 13 ppm.

Arsenic concentrations were less than 13 ppm for all samples (including shallow soils) collected in B-4 and B-5. There is insufficient data to establish whether the lower concentrations at B-4 and B-5 represent true background levels.

Cadmium concentrations ranged from 0.9 ppm to 14.7 ppm, and were above the naturally-occurring level of 0.06 ppm in all 42 samples. Furthermore, all test samples were above the indicator concentration of 0.12 ppm. Based on a subjective review, the highest cadmium concentrations were located near surface and decreased with depth. Since all the samples exceeded the indicator value and the naturally occurring level, these literature-based values may not be valid for the site.

Chromium in soil from MW-2 at 25 feet yielded an anomalous concentration of 681 ppm total chromium, and was the only result above the naturally-occurring level of 70 ppm (Shacklette and Boerngen, 1984). This was also the only sample that had chromium concentrations above the indicator level of 140 ppm. The 681 ppm chromium sample location was coincident or below the water table elevation, and was also coincident with the highest concentration of TCE in groundwater. The remaining 41 chromium concentrations ranged from 2.7 ppm to 36.8 ppm, and were less than the naturally occurring level.

Well B-3, which exhibits the second highest concentration of TCE, was not sampled at an equivalent level to provide comparison. A subjective review of the chromium data indicates that the highest concentrations were generally yielded by samples in the upper 10 feet of soil. The validity of the 681 ppm chromium result is inconclusive, and may warrant further investigation.

Lead concentrations ranged from 2.72 ppm to 27.9 ppm, and were above the naturally-occurring level of 15 ppm in 8 of the 42 total samples (Shacklette and Boerngen, 1984). Concentrations over 15 ppm were found only in samples collected in the upper five feet of soil. None of the samples exhibited lead concentrations greater than the indicator value of 30 ppm.

Silver concentrations ranged from ND to 3.7 ppm, and were above the naturally occurring level of 0.1 ppm in 40 of 42 samples (Shacklette and Boerngen, 1984). The detection limit reported for the ND samples was 0.5 ppm, which is above the literature based natural and indicator levels. Since all reported detectable levels were in excess of the natural and indicator levels, the literature based criteria may not be valid for these

soils. Based on a subjective review of the data, silver concentrations decrease with depth.

A summary of the analytical results is presented in Table IV. The analytical laboratory reports and chain of custody records are presented in Appendix D.

5.3 WATER - 1989

In 1989, a single water sample was collected from the open boring at location B-4A. This sample was collected with a disposable bailer after purging the boring and allowing groundwater recovery. This sample was analyzed for volatiles (8240) and TPH (418.1). The result of this analysis produced a TPH concentration of 7.5 ppm. In contrast to the soil data at Boring B-4A, Tetrachloroethene was not detected. Trichloroethane and 1,1,2,2 Tetrachloroethane were found in concentrations of 13 ppb and 3.3 ppb respectively. A summary of the analytical results is presented on the last column of Table III. The Analytical Lab Report is presented in Appendix C.

5.4 WATER - 1991

Water samples were collected from the monitoring wells during three separate events in May, June and August 1991 (see Section 3.6). Wells MW-1, MW-2 and MW-3 were sampled during all three events. Wells B-1 through B-5 were sampled only in June and August. Samples collected in May and June 1991 were analyzed for volatile organic compounds (VOCs) by EPA Method 8240, semivolatile organic compounds (SVOCs) by EPA Method 8270 and total petroleum hydrocarbons (TPH) by EPA Method 418.1.

Groundwater samples were also tested for metals content. Total arsenic (As) was tested by Method 206.2, barium (Ba) by Method 200.7, cadmium (Cd) by Method 200.7, chromium (Cr) by Method 200.7, lead (Pb) by Method 239.2, mercury (Hg) by Method 245.1, selenium (Se) by Method 270.2, and silver (Ag) by Method 272.1.

Samples collected in August 1991 were analyzed for VOCs only.

Results of VOC Testing

Groundwater testing indicated that trichlorethene (TCE) was the predominant volatile organic compound (VOC) present in area groundwater. TCE was reported in eight wells at concentrations ranging from 6 ppb to 5700 ppb. Well MW-2 yielded the highest TCE levels ranging from 3300 ppb to 5700 ppb. Well B-3, which is located approximately 200 feet southwest of MW-2, yielded TCE results ranging from 2450 to 3400 ppb. The remaining wells exhibited TCE concentrations less than or equal to 217 ppb.

Additional VOCs reported in groundwater samples and the maximum concentration reported included the following: vinyl chloride 20 ppb, dichloromethane 18 ppb, carbon disulfide 49 ppb, 1,1-dichloroethene 31 ppb, 1,1-dichloroethane 6 ppb, 1,2-dichloroethene 417 ppb, chloroform 2 ppb, 1,2-dichloropropane 33 ppb, tetrachloroethene 27 ppb, toluene 19 ppb, chlorobenzene 19 ppb, ethylbenzene 8 ppb, styrene 2 ppb, and xylenes 22 ppb. QA/QC data supports the possibility that dichloromethane, toluene, ethylbenzene, styrene and xylenes may be false positive results. The assessment regarding potential for false positive test results could be qualified by a more stringent QA/QC program and additional monitoring. Groundwater analytical test data are summarized in Table V.

Results of SVOC Testing

SVOC testing was performed on samples collected in May and June 1991. Well B-1 was not tested for SVOCs in June, 1991 due to an insufficient amount of water in the well.

Bis (2-ethyl hexyl) phthalate was the only SVOC reported during the testing program. Bis (2-ethyl hexyl) phthalate was reported only during the June 1991 testing event, and was reported for MW-2 at a concentration of 16 ppb and for B-2 at a concentration of 16 ppb, and B-4 at a concentration of 11 ppb.

Bis (2-ethyl hexyl) phthalate was not reported for any of the field or the laboratory's interval QA/QC samples.

Results of TPH Testing

TPH analyses were performed on water samples collected in May and June 1991. TPH results were non-detectable at a detection limit of 2 ppm for all water samples.

Results of Metals Testing

Total metals analyses were performed on water samples collected in May and June 1991. Well B-1 was not tested for metals in June 1991 due to an insufficient amount of water in the well. Barium and selenium are the only metals which were reported at detectable levels. Dissolved barium concentrations ranged from non-detectable to 0.1 ppm. Dissolved selenium concentrations ranged from non-detectable to 0.01 ppm. The presence of barium in groundwater is consistent with the geological source materials, which the soil testing program indicated to contain up to 197 ppm total barium.

A summary of the analytical results is presented on Table V. The analytical laboratory reports and chain-of-custody records are presented in Appendix E.

5.5 FIELD QUALITY ASSURANCE RESULTS

Nine (9) samples were collected in the field for quality assurance purposes. These included one sample of rinsate water from split spoon sampler decontamination, four samples of rinsate water from water level meter decontamination, and four trip blanks of clean, deionized water which accompanied water sample jars during transport activities. Two of the aforementioned QA/QC samples yielded detectable levels of specific analytes.

A trip blank for the 8/1/91 sample event yielded concentrations of toluene, ethylbenzene, styrene and xylenes. These constituents were not detected at the site during any previous sampling event. Precision Analytics, Inc, which performed the 8/1/91 analytical testing, did not provide any internal QA/QC method blank data. Therefore, it was not possible to evaluate if the contaminants found in the 8/1/91 trip blank were introduced into the sample by laboratory or field conditions.

A rinse sample collected on 4/23/91 yielded 10 ppb of dichloromethane (also known as methylene chloride). This sample was collected following the decontamination of soil sampling equipment. Professional Services Industries (PSI), which performed this analysis, also provided internal QA/QC method blank data. The method blank results yielded a dichloromethane concentration of 12 ppb. Based on these data, the presence of dichloromethane in the rinse sample may be attributed to contamination introduced by the laboratory environment. A summary of the analytical results is presented in Table VI. The analytical reports are presented on Appendix F.

5.6 SAMPLE IDENTIFICATION NUMBERS

Soil samples collected during April 1991 labeled B-1, B-2 and B-3 were collected from soil borings in which wells MW-1, MW-2 and MW-3 were installed. The laboratory results are referred to as the results of soil samples collected from MW-1, MW-2 and MW-3 in the report and figures.

Soil samples collected during June 1991 labeled B-1A, B-2 and B-3 were collected from three soil borings separate from those drilled in April 1991. The laboratory results form these three borings are referred to as the results of soil samples collected from B-1, B-2 and B-3 in the report and figures.

6.0 DISTRIBUTION OF DISSOLVED CONTAMINANTS IN GROUNDWATER

The concentrations of trichloroethene and total volatiles were plotted and contoured for the monitoring events dated June 25 and August 1, 1991 (see Figures 22-25). Isopleths of dissolved TCE concentrations are highly skewed by the MW-2 and MW-3 data outliers such that the isopleth patterns do not allow inference of flow direction with a high degree of confidence.

Wells MW-1 and B-1, which are nearest to the reported still location, did not yield levels of TCE greater than 10 ppb. Based on these observations, the theory that the source of TCE in groundwater was proximal to the former still location is not supported at this time.

The groundwater elevation data obtained indicated highly divergent flow potentials in the vicinity of MW-2, where dissolved TCE concentrations were highest. Because of the divergent flow potentials, conclusive interpretations of future TCE migration directions can not be performed. Furthermore, the point(s) of origin of TCE into the saturated unit can not be predicted with a high degree of certainty. Additional control points, dissolved VOC sampling, and water level measurements will be required to make qualified interpretations.

Since TCE was present at concentrations well below its solubility limit in water, which is approximately 1100 ppm, the migration of TCE is assumed to be the result of advection by groundwater flow. To evaluate the possibility that TCE migrated as a separate, or nonaqueous phase, a topographic map of the lower confining unit (Navarro-alluvium contact) was constructed. The distribution of TCE was not consistent with the bedrock topographic slope or the reported former still location. However, it should be noted that the structure or degree of slope required to influence phase separated TCE movement may not be resolved until additional elevation data for the Navarro is obtained.

A plume with a southwest elongation or potential trend is delineated through the contouring process.

7.0 CONCLUSIONS

Based on the data collected, the following conclusions were developed.

Hydrogeology

1. The IS-1 site is underlain by Quaternary age alluvium which ranges in thickness from 14 to 28 feet. The alluvium contains an unconfined aquifer which exhibits saturated thicknesses ranging from 0 to 4.5 feet. The aquifer's lower confining unit is an irregular erosional surface which may influence the occurrence and movement of groundwater and possible contaminants.

Groundwater Analyses

2. Groundwater testing indicated that trichlorethene (TCE) was the predominant volatile organic compound (VOC) present in area groundwater. TCE was reported in eight wells at concentrations ranging from 6 ppb to 5700 ppb. Well MW-2 consistently yielded the highest TCE levels ranging from 3300 ppb to 5700 ppb. The second highest TCE levels were consistently observed in samples from B-3 at concentrations ranging from 2450 ppb to 3400 ppb.

3. The mechanisms to account for the distribution of TCE are not known. Groundwater data indicated highly divergent flow potentials in the vicinity of MW-2, where dissolved TCE concentrations were highest. Conclusive interpretations of past or present TCE migration directions can not be performed at this time. It is not known if the concentrations of TCE in MW-2 and B-3 are related, or the result of different TCE sources. TCE migration as a phase separated product is not supported by the TCE concentration data or the slope of the Navarro contact between MW-2 and B-3.

4. Wells MW-1 and B-1, which are nearest to the reported still location, did not yield levels of TCE greater than 10 ppb. Based on these observations, the theory that the source of TCE in groundwater was proximal to the former still location is not supported at this time.

5. Additional VOCs reported in groundwater samples and the maximum concentration reported included the following: vinyl chloride 20 ppb, dichloromethane 18 ppb, carbon disulfide 49 ppb, 1,1-dichloroethene 31 ppb, 1,1-dichloroethane 6 ppb, 1,2-dichloroethene 417 ppb, chloroform 2 ppb, 1,2-dichloropropane 33 ppb, tetrachloroethene 27 ppb, toluene 19 ppb, chlorobenzene 19 ppb, ethylbenzene 8 ppb, styrene 2 ppb, and xylenes 22 ppb.

6. QA/QC data supports the possibility that dichloromethane, toluene, ethlybenzene, styrene and xylenes may be false positive groundwater results.

Soil Analyses

7. Soil testing did not yield detectable levels of TCE in the unsaturated zone. The fact that such compounds were not identified in soils indicates the source(s) of groundwater contaminants was not identified. The available data is insufficient to determine if dissolved TCE is the result of a single release location and subsequent migration within the water bearing zone, or multiple releases.

   The soil and groundwater data may be consistent with one of the following conclusions: 1) no releases occurred at the location of the former recovery still, 2) the precise location of the still was not identified and investigated. 3) More than one source of TCE may be present.

8. The only VOCs reported in soil tests include dichloromethane and acetone. QA/QC data supports the possibility that some reports of these compounds may be false positives.

9. Soil TPH concentrations ranged from non-detectable (30 ppm detection limit) to 134 ppm. No strong correlations of TPH concentration versus depth were apparent based the available data. However, elevated TPH concentrations at MW-1 and MW-2 at 0.5 feet could be the result of the accumulation of surface runoff in vehicle use areas.

10. A literature source was utilized to initiate the assessment of the metals testing data. Based on Table 4-1 of NUS Corporation's February 1991 report to KAFB titled "Final Draft Remedial Investigation Report, Site S-1", arsenic, cadmium, chromium, lead and silver were detected in concentrations above naturally occurring levels. None of the lead concentration values exceeded the indicator value of 30 ppm.

    The samples which yielded concentrations above the literature-based naturally occurring and/or indicator levels may warrant additional investigation to qualify if they are in fact elevated beyond background levels.

8.0 RECOMMENDATIONS

Based on the data collected, the following course of action is recommended.

* If the location of the former solvent still is correct, and the borings/wells installed during this investigation were actually located at the most probable spill location, then presently

no further action is warranted regarding VOCs and SVOCs in soils. The site investigation may be re-opened if changes in the current regulations or in site conditions warrant further studies.

* A risk assessment will be conducted in consideration of metals to determine site closure.

* Groundwater elevation and chemical data from any adjacent sites, if available, should be utilized to qualify the groundwater flow direction data at Site IS-1.

* Additional groundwater investigations should be conducted and should include the following tasks:

  * A groundwater monitoring and sampling program should be implemented to qualify groundwater flow directions and VOC levels and guide the placement of additional monitoring wells.

  * The groundwater sampling plan should include, at a minimum, VOC analyses, field pH measurements and total dissolved solids analyses (Method 160.1).

  * A QA/QC groundwater sampling, handling, laboratory analysis plan, should be developed and strictly implemented to qualify groundwater chemical data.

  * The extent of dissolved TCE in groundwater should be delineated with additional monitoring wells. Monitoring results should be utilized to predict the origin of the TCE plume(s).

* KAFB should gather any available data, to determine the most probable location for TCE entrance to the soil zone.

* The vertical and horizontal extent of VOCs in identified source areas should be delineated.

9.0 LIMITATIONS

The conclusion presented in this report are based on the work performed. Additional investigation at the site may alter our findings.

Questions concerning this report should be directed to our office at 1850 Grandstand Drive, San Antonio, Texas 78238, (512) 680-5023.

TABLE III
SUMMARY OF ANALYTICAL RESULTS-SOIL DATA-SEPTEMBER 1989

COMPOUND	BORING NUMBER AND DEPTH OF SAMPLE							
	B-1A @ 0'	B-1A @ 2'	B-1A @ 4'	B-2A @ 0'	B-2A @ 2'	B-2A @ 4'	B-3A @ 0'	B-3A @ 2'
Volatile Organics(ppm):								
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND
Chlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND
Styrene	ND	ND	ND	ND	ND	ND	ND	ND
Petroleum Hydrocarbons(ppm)	518	ND	20.3	295	653	10	54.2	ND

COMPOUND	BORING NUMBER AND DEPTH OF SAMPLE								
	B-3A @ 4'	B-4A @ 0'	B-4A @ 2'	B-4A @ 4'	B-4A @ 9'	B-4A @ 14'	B-4A @ 19'	B-4A @ 24'	Ground-Water
Volatile Organics(ppm):									
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	**	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	5.7	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	**	ND
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	3.6	13
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	10	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	143.3	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	3.3
Toluene	ND	ND	ND	ND	ND	ND	ND	**	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	**
Chlorobenzene	ND	ND	ND	ND	ND	ND	ND	**	ND
Styrene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Xylenes	ND	ND	ND	ND	ND	ND	ND	**	ND
Petroleum Hydrocarbons(ppm)	136	19.7	19.5	ND	ND	518	ND	104	7.5

Notes:
1. "ND" indicates the constituent was not detected.
2. "NA" indicates the constituent was not analyzed.
3. Constituents that were not detected throughout this study are omitted from this table.
4. The locations of the soil borings is indicated on Figure 2.
5. The asterisks indicate that the compound was detected, but at a concentration below the recoginzed quantitative limit. The laboratory did not indicate a concentration for these compounds.
6. The soil samples were collected on September 22, 1989.
7. The single groundwater sample was collected from B-4A on September 22, 1991.

TABLE IV

SUMMARY OF ANALYTICAL RESULTS

SOIL DATA - SPRING 1991

COMPOUND	BORING/WELL NUMBER AND DEPTH													
	MW-1 @ 0.5'	MW-1 @ 5'	MW-1 @ 10'	MW-1 @ 15'	MW-1 @ 20'	MW-1 @ 25'	MW-2 @ 0.5'	MW-2 @ 5'	MW-2 @ 10'	MW-2 @ 15'	MW-2 @ 20'	MW-2 @ 25'	MW-3 @ 0.5'	MW-3 @ 5'
Volatile Organics (ppm):														
Dichloromethane	4.4	4	3.2	1.1	2	1.8	0.9	0.3	0.9	0.6	ND	ND	ND	ND
Acetone	0.7	ND	0.3	0.3	ND	ND	1.1	0.7	0.3	0.4	0.3	0.3	1	0.5
Semivolatile Organics (ppm):														
Bis (2-ethyl hexyl) Phthalate	ND	ND	0.66	0.74	ND	ND	ND	ND	0.9	0.85	ND	ND	ND	0.9
Petroleum Hydrocarbons (ppm):	106	68	70	63	61	59	134	47	60	31	35	51	64	44
Metals (ppm) :														
Arsenic	41.3	31.5	26.1	15.6	12.1	7.58	8.39	18.1	32.8	24.1	24.7	22.4	22.6	22
Barium	197	136	72.5	51.2	30.6	17	154	8.8	71.7	51.5	44.1	37.3	136	184
Cadmium	8.9	6.7	4.7	3.2	2.1	1.4	5.2	5.3	10.8	5.5	6.3	11.6	14.7	11.9
Chromium	29	29.5	2.7	16.7	10.5	9.1	28.4	11.3	29.2	17.6	19.6	681	36.8	33.2
Lead	27.9	13.6	12.1	9.2	5.52	2.13	22	15.5	11.1	6.59	7.19	5.31	26	25.6
Mercury	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver	1.9	1.3	1.4	3	3	3.3	2.6	1.8	2.2	2.9	2.7	2.4	2.04	1.8
Selenium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes:

1. "ND" indicates the constituent was not detected.
2. "NA" indicates the constituent was not analyzed.
3. Constituents that were not detected throughout this study are omitted from this table.
4. The location of the borings are shown on Figure 2.

TABLE IV

(CONTINUED)

COMPOUND	BORING/WELL NUMBER AND DEPTH													
	MW-3 @ 10'	MW-3 @ 15'	MW-3 @ 20'	MW-3 @ 25'	MW-4 @ 2.5'	MW-4 @ 10.0	MW-4 @ 17.5	MW-4 @ 22.5	B-1 @ 2.5'	B-1 @ 10'	B-1 @ 15'	B-1 @ 20'	B-2 @ 2.5'	B-2 @ 10'
Volatile Organics (ppm):														
Dichloromethane	ND	ND	ND	ND	0.3	0.7	0.5	0.7	0.3	ND	ND	ND	2.6	0.4
Acetone	ND	ND	0.3	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Semivolatile Organics (ppm):														
Bis (2-ethyl hexyl) Phthalate	ND	2.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Petroleum Hydrocarbons (ppm)	24	33	87	33	31	ND	ND	ND	ND	ND	ND	ND	30.4	32.8
Metals (ppm) :														
Arsenic	14.6	9.78	6.97	7.93	31.3	7.3	11.5	14.2	32.5	11	10.2	9.1	18.1	14.4
Barium	56.6	32	126	60.3	140	25.3	23.7	22.2	187	45	38.5	43.2	175	51.2
Cadmium	14.6	4.8	3.3	5.5	6.3	1.7	1.9	2.2	7.5	4.2	3.2	3	6.24	4.8
Chromium	30.7	15.6	11.9	12.2	25.9	8.3	10.9	10.2	31.3	15.4	13.8	19.8	33	22.9
Lead	12.2	6.92	12	5.36	18.6	4.7	4.66	4.35	20.3	9.38	9.09	6.7	15.6	8.51
Mercury	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver	3.04	3.03	3.5	3.2	1.4	4	3.7	3.1	1.9	2.8	3.1	3.6	ND	0.979
Selenium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes:

1.) "ND" indicates the constituent was not detected.

2.) "NA" indicates the constituent was not analyzed.

3.) Constituents that were not detected throughout this study are omitted from this table.

4. The location of the borings are shown on Figure 2.

5. The soil samples were collected between 4/15/91 and 6/14/91.

TABLE IV

(CONTINUED)

COMPOUND	BORING/WELL NUMBER AND DEPTH													
	B-2 @ 20'	B-2 @ 25'	B-3 @ 2.5'	B-3 @ 10'	B-3 @ 15'	B-3 @ 22.5	B-4 @ 2.5'	B-4 @ 10'	B-4 @ 15'	B-4 @ 20'	B-5 @ 2.5'	B-5 @ 10'	B-5 @ 15'	B-5 @ 20'
Volatile Organics (ppm):														
Dichloromethane	ND	0.6	0.8	2.7	6.8	1.6	0.5	0.4	3.2	3.9	0.6	0.8	0.6	0.8
Acetone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Semivolatile Organics (ppm):														
Bis (2-ethyl hexyl) Phthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Petroleum Hydrocarbons (ppm)	ND	31.5	ND	ND	ND	ND	36.2	17	16.9	19	15.5	5.16	16.1	27.3
Metals (ppm) :														
Arsenic	6.2	11.2	20.2	19.2	8	5.9	12.5	3.9	ND	4.3	11	6.3	7.7	5.2
Barium	54.9	22.7	166	73.6	35.8	13.5	154	37.4	28	23	114	34.5	39.3	27.6
Cadmium	1.7	3.04	6.2	4.8	2.36	1.31	6.01	2	0.9	2.1	4.8	2.23	3.1	2.3
Chromium	9.3	24.3	25.5	18.1	11.1	10	28	8.6	3.7	9.2	22.2	10.7	13.8	11
Lead	4.16	3.83	13.2	8.5	4.35	2.72	14.3	8.08	2.76	4.53	17.7	5.17	7.36	3.35
Mercury	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver	1.49	ND	ND	0.83	1.42	1.96	1	1.8	1.9	2	1.2	1.7	2.1	1.9
Selenium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes:

1.) "ND" indicates the constituent was not detected.

2.) "NA" Indicates the constituent was not analyzed.

3.) Constituents that were not detected throughout this study are omitted from this table.

4. The location of the borings are shown on Figure 2.

5. The soil samples were collected between 4/15/91 and 6/14/91.

TABLE V

SUMMARY OF ANALYTICAL RESULTS

GROUNDWATER–SPRING AND SUMMER 1991

COMPOUND	WELL NUMBER AND DATE OF SAMPLING									
	MW-1 (May)	MW-1 (Jun)	MW-1 (Aug)	MW-2 (May)	MW-2 (Jun)	MW-2 (Aug)	MW-3 (May)	MW-3 (Jun)	MW-3 (Aug)	MW-4 (Jun)
Volatile Organics (ppb):										
Vinyl Chloride	ND	ND	ND	ND	ND	20	ND	ND	ND	ND
Dichloromethane	16	ND	ND	18	ND	ND	16	ND	ND	ND
Carbon Disulfide	ND	ND	ND	ND	49	ND	ND	ND	ND	ND
1,1-Dichloroethene	ND	ND	ND	ND	ND	31	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	6	ND	ND	ND	ND
1,2-Dichloroethene	NA	NA	ND	NA	NA	ND	NA	NA	10	NA
2-Butanone	ND	ND	ND	ND	ND	1050	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	4	ND	ND	ND	ND
1,2-Dichloropropane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	10	ND	44	3300	5700	4970	110	83	37	ND
Benzene	ND	ND	ND	ND	ND	2	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	14	11	ND	27	ND
Toluene	ND	ND	9	ND	ND	5	ND	ND	11	ND
Chlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	5	ND	ND	3	ND
Styrene	ND	ND	ND	ND	ND	2	ND	ND	ND	ND
Total xylenes	ND	ND	7	ND	ND	12	ND	ND	8	ND
Semivolatile Organics (ppb):										
Bis (2-ethyl hexyl) Phthalate	ND	ND	NA	ND	16	NA	ND	ND	NA	ND
Petroleum Hydrocarbons (ppm) :	ND	ND	NA	ND	ND	NA	ND	ND	NA	ND
Metals (ppm) :										
Barium	0.05	0.08	NA	0.10	0.08	NA	0.07	0.04	NA	0.01
Selenium	ND	ND	NA	ND	ND	NA	ND	0.01	NA	ND

Notes:

1. "ND" indicates the constituent was not detected.
2. "NA" indicates the constituent was not analyzed.
3. Constituents that were not detected throughout the study are omitted from this table.

TABLE V

(CONTINUED)

COMPOUND	WELL NUMBER AND DATE OF SAMPLING										
	MW-1 (Aug)	B-1 (Jun)	B-1 (Aug)	B-2 (Jun)	B-2 (Aug)	B-3 (Jun)	B-3 (Aug)	B-4 (Jun)	B-4 (Aug)	B-5 (Jun)	B-5 (Aug)
Volatile Organics (ppb):											
Vinyl Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Disulfide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	ND	ND	ND	ND	ND	ND	5	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethene	ND	NA	ND	NA	3	NA	417	NA	ND	NA	2
2-Butanone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	ND
1,2-Dichloropropane	ND	ND	ND	ND	ND	ND	33	ND	ND	ND	ND
Trichloroethene	ND	ND	6	44	55	3400	2540	110	217	ND	35
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	11	ND	20	ND	10	ND	2	ND	ND
Toluene	19	ND	11	ND	2	ND	4	ND	15	ND	3
Chlorobenzene	19	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	8	ND	ND	ND	ND	ND	ND	ND	2
Styrene	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	ND
Total xylenes	22	ND	ND	ND	5	ND	2	ND	ND	ND	ND
Semivolatile Organics (ppb):											
Bis (2-ethyl hexyl) Phthalate	NA	ND	NA	16	NA	ND	NA	11	NA	ND	NA
Petroleum Hydrocarbons (ppm) :	NA	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA
Metals (ppm) :											
Barium	NA	NA	NA	0.03	NA	0.05	NA	0.09	NA	0.10	NA
Selenium	NA	NA	NA	0.01	NA	ND	NA	ND	NA	ND	NA

Note:

1. "ND" indicates the constituent was not detected.
2. "NA" indicates the constituent was not analyzed.
3. Constituents that were not detected throughout the study are omitted from this table.

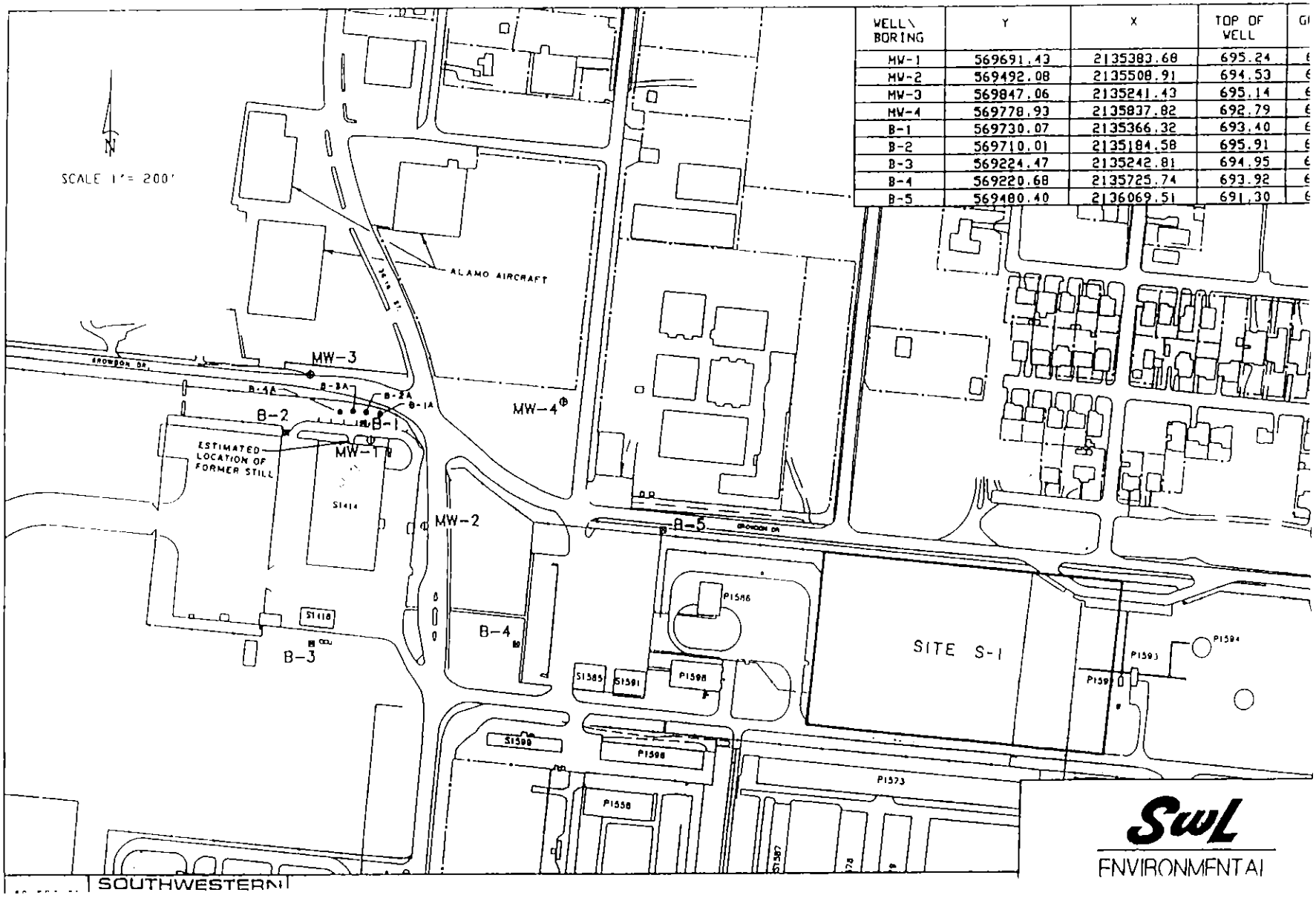
TABLE VI

SUMMARY OF ANALYTICAL RESULTS
QUALITY ASSURANCE/QUALITY CONTROL

COMPOUND	SAMPLE NAME	
	TRIP BLANK 8/1/91	RINSE 4/23/91
Volatile Organics (ppb):		
Dichloromethane	0	10**
Toluene	4*	0
Ethylbenzene	8	0
Styrene	3*	0
Total Xylenes	32	0
TOTAL ALL VOLATILES	47	10

* Compound was detected, but below laboratory quantitative reporting limit.
** Compound was detected in laboratory analytical blank as well.

Note: A total of nine samples were collected and analyzed for quality assurance purposes (See Section 3.7). Only two of the nine samples produced detectable concentrations of organic constituents. Samples which did not produce detectable concentrations are excluded from this table.



WELL\ BORING	Y	X	TOP OF WELL	GI
MW-1	569691.43	2135383.68	695.24	6
MW-2	569492.08	2135508.91	694.53	6
MW-3	569847.06	2135241.43	695.14	6
MW-4	569778.93	2135837.82	692.79	6
B-1	569730.07	2135366.32	693.40	6
B-2	569710.01	2135184.58	695.91	6
B-3	569224.47	2135242.81	694.95	6
B-4	569220.68	2135725.74	693.92	6
B-5	569480.40	2136069.51	691.30	6

Appendix B

Zone 5 Sanitary Sewer Line Investigation Data Summary

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APPENDIX B

Zone 5 Sanitary Sewer Line Investigation Data Summary Package

1.0 Introduction

The previous Zone 5 Remedial Investigation (RI) and other investigations have provided data that indicate some sanitary sewer lines within Zone 5 that may be a source of soil and groundwater contamination. The Zone 5 Sanitary Sewer Line Investigation was performed to collect and analyze soil gas and soil samples from selected locations along the sanitary sewer lines within Zone 5. This report summarizes the results of this limited investigation to determine if soil source sites exist along sanitary sewer lines.

1.1 Purpose and Scope

The purpose of the investigation was to determine if the sanitary sewers are a potential source of contaminants within Zone 5. Five specific areas within Zone 5 were investigated as potential sources (Figure 1). Soil gas and soil samples were collected within the backfill of the sanitary sewer trench and analyzed immediately on-site for chlorinated volatile organic compounds (CVOCs) by Transglobal Environmental Geochemistry (TEG) personnel in a mobile environmental laboratory. The following sampling events were conducted from September 4,1997 to September 18,1997:

- A total of 141 soil gas samples were collected from the five study areas and analyzed for volatile aromatic and halogenated hydrocarbons with the United States Environmental Protection Agency (EPA) Method 8010/8020.
- A total of 11 soil samples were collected from two of the five study areas and analyzed for volatile aromatic and halogenated hydrocarbons with EPA Method 8010/8020.

The following sections describe the sample location selection process (Section 1.2), provide the field procedures (Section 2.0), summarize the soil gas and soil sample analytical results (Section 3.0), and evaluate the results with respect to previous data (Section 4.0).

1.2 Sample Location Selection Process

1.2.1 Study Area Selection

Five study areas were selected for this investigation. The areas were selected in a two-step process. First, areas were identified where known groundwater contaminant plumes show the highest concentrations. The upgradient areas of the highest known concentrations of contaminants have the most potential of being close to the original sources of contamination. Second, inspection records of the sanitary sewer lines located in the vicinity of the plume areas were reviewed to identify evidence of potentially leaky pipe. The type of evidence includes the following:

- Possible obstructions, such as roots
- Pipelines that are cracked or have offset joints
- Pipelines that have low points that could pond water
- Pipelines that are known to have surcharge conditions

The following five areas were identified where potentially leaky pipes coincided with the high concentration portions of groundwater contaminant plumes:

- Building 1530 is located on a trichloroethene (TCE) and dichloroethene (DCE) plume at the northeast part of Zone 5. High concentrations of TCE (> 1,000 micrograms per liter [µg/L]) and DCE (> 100 µg/L) were detected in the groundwater monitoring wells just north of the building. Minor sediment and possible backup and leakage were reported at the sanitary sewer line sections P137, P138, P139 and P140.
- The 1600 Area is located on a TCE plume in the eastern part of Zone 5. The sanitary sewer lines in the area are located upgradient (northwest) of monitoring well SS050MW113, which has a high concentration of TCE (240 µg/L) in the groundwater. Cracked pipes and root obstructions were reported in the sanitary sewer line sections P206, P208, P216 and P217.
- Building 1414 is near the upgradient (or northern) end of the TCE and DCE plume in the northeast part of Zone 5 (the same plume as in Building 1530 area). The sanitary sewer line sections P132, P133 and P134 reportedly had possible obstructions from roots that have caused backup and leakage. Building 1414 also housed the former solvent still that was previously investigated as a potential source of the TCE plume (Installation Restoration Program [IRP] Site IS-1).
- The 1100 Area is located on the northern part of a tetrachloroethene (PCE) plume at the western part of Zone 5. The sanitary sewers in the area are located in the northern (or upgradient) end of the PCE plume. The highest detected PCE concentration in this plume was 120 µg/L. In addition to PCE, relatively low concentrations of TCE (≤ 8 µg/L) and DCE (≤ 23 µg/L) were also detected at the south side of the sanitary sewer line. Vertical curvature , surcharge, and root obstruction conditions were reported at the sanitary sewer pipe sections L055, P089, and P090, respectively. Sediments were observed in sanitary sewer lines L055, P073, P088, P089 and P090.
- The South Flight Line Area is located on the northern part of a PCE plume in the southern area of Zone 5. PCE was detected at a concentration of 1,300 µg/L in a groundwater sample collected from monitoring well SS050MW106, which is located on the south side of the sanitary sewer line. TCE (79 µg/L) and DCE (290 µg/L) concentrations were also detected in the groundwater sample. Defective joints, cracked pipes, and surcharged conditions were reported in the sanitary sewer pipe sections P365 and P366.

1.2.2 Sample Locations

Figures 2 through 6 show the soil gas and soil sampling locations in the five study areas. In general, the soil gas sample locations were spaced approximately 50 feet apart along the sanitary sewer lines. A location close to the sewer was maintained so that soil gas from the

backfill of the original sewer trench could be extracted. The depth of the soil gas sample was 1 to 2 feet above the sewer to avoid damage to the line (sanitary sewers are generally about 3 to 10 feet below ground surface [bgs]). The depth of the sewer was determined in the field by removing the manhole lids and measuring the sewer depth and pipe diameter with a tape measure.

Where initial soil gas samples detected contaminants, additional new sampling locations between the previous locations were selected to confirm the occurrence of contamination along the sewer lines. Once the areas of soil gas contamination were determined, soil borings were drilled to evaluate the presence and concentration of contaminants in the soil below and immediately adjacent to the sanitary sewer.

The selected soil gas and soil sampling locations in each area, shown in Figures 2 through 6, are summarized below:

- Five soil gas samples at five locations were collected from the P139 section of the sanitary sewer at southwest of Building 1530 (Figure 2). No soil samples were collected in this area.
- Thirty-two soil gas samples at 32 locations were collected from the P202, P206, P208, P216, P217 sections, and surrounding perimeter areas of the sanitary sewers to the south and east of Building 1628 (Figure 3) in the 1600 Area. No soil samples were collected in this area.
- Forty soil gas samples at 35 locations were collected from the P132, P133, P134, and P135 sections of the sanitary sewers to the east and south of Building 1414 (Figure 4). Five soil borings were drilled in the Building 1414 Area, and ten soil samples were collected.
- Thirty-four soil gas samples from 34 locations were collected from the P073, P088, P089, P090, and L055 sections of the sanitary sewers (Figure 5) in the 1100 Area. No soil samples were collected in this area.
- Thirty soil gas samples at 21 locations were collected from the P365 and P366 sections of the sanitary sewer crossing the east parallel taxiway between Taxiway 4 and Taxiway 5 (Figure 6) in the South Flight Line Area. One soil boring was drilled in the Flight Line Area, and one soil sample was collected.

2.0 Field Procedures

2.1 Soil Gas Sampling Procedures

Soil gas samples were collected by TEG's soil vapor probes, which are constructed of 1-inch outside diameter (OD) hardened steel rod, equipped with expendable tips. An inert 1/8-inch nylaflow tube was then inserted through the center of the probe rod to the expendable point holder above the tip. The probe was driven into the ground by the force of a high frequency hydraulic hammer. Once inserted to the desired depth, the probe rod was withdrawn approximately one-half of an inch, which allowed the expendable tip to remain in the ground and open the end of the rod. The nylaflow line was purged by withdrawing 120 cubic centimeters (cc) of soil gas using a 20 cc, air-tight syringe. The next 20 cc of soil gas were withdrawn in a different clean, glass, air-tight syringe and transported to the mobile lab for analysis within minutes of collection. The rod was removed, and the hole was

backfilled with bentonite pellets. The surface was repaired to the original condition (i.e., asphalt or soil).

To minimize the potential of cross-contamination between sites, all probe parts were cleaned of excess dirt and moisture prior to insertion. The rod and expendable points were flushed prior to usage using a high-pressure washer. The nylaflow tubing was replaced if the laboratory results showed a significant concentration of contaminants. The glass air-tight syringes were washed in an Alconox solution, triple rinsed, and allowed to air dry prior to taking the next sample.

2.2 Soil Sampling Procedures

Soil borings were drilled at locations where the previously collected soil gas samples indicated significant levels of CVOCs. The soil borings were continuously logged from the surface to refusal. The cores were collected by pushing a 2-inch by 2-foot split-spoon sampler with the high frequency hydraulic hammer. After the sampling interval (2 feet) had been reached, the probe rod was withdrawn from the bore hole along with the sampler. The cutting shoe was removed, and the sample (encased in an acetate sleeve) was withdrawn. A clean sampler with a new acetate sleeve was run back into the boring to advance through the next core interval. The sleeves were cut open and an organic vapor monitor (OVM) reading was taken at several locations along the core. The samples with relatively high OVM readings were placed in 4-ounce glass jars and delivered to the mobile laboratory for immediate CVOC analysis. The process was repeated until the core barrel encountered refusal. The borings were then backfilled with bentonite pellets. The surfaces were restored to the original conditions (i.e., asphalt or soil). The soil boring logs are attached in Appendix A.

The back of the probing unit and all down-hole tools were steam cleaned with an Alconox solution prior to moving onto a new site and between each sampling location. The tools were triple rinsed with DI water, methanol, and hexane, and allowed to air dry. The samplers were wrapped in aluminum foil prior to use. Clean samplers and new acetate sleeves were used for each sample interval.

2.3 Quality Assurance/Quality Control (QA/QC) Documentation Procedures

Quality control (QC) samples were collected daily to ensure that no cross contamination or laboratory contamination was encountered. For soil gas sample analysis, equipment blanks were collected every morning and after every sample with significantly high concentrations of CVOCs. The samples were collected by purging 120 cc of air from the nylaflow line using the glass, air-tight syringe. The next 20 cc were withdrawn and injected in the gas chromatograph (GC) for analysis. Standards were injected every morning, every evening, and every mid-day (depending on how many samples were collected during the morning). For soil sample analysis, a solvent was collected in the morning and after every significantly high concentration sample. Standards were run every morning and evening. For all the samples, a matrix spike/matrix spike duplicate (MS/MSD) and duplicate was run every 20 samples. Surrogates were added to all the samples including blanks and standards.

3.0 Data Summary

3.1 Survey Location

Sample locations and ground surface elevations are shown in Table 1. For each sample location, the sample depth, sample number, and collection time are shown in Tables 2 through 6.

3.2 Soil Organic Vapor (SOV) Results

3.2.1 Building 1530 Area

Table 2 shows the data obtained from the Building 1530 area. Organic contaminants were not detected in the area. Encountering contaminants in this area was expected to have a low probability because it is a relatively new facility with a recently installed sanitary sewer line. The original sanitary sewer was removed or abandoned in place when Building 1530 was constructed. Therefore, the investigation was terminated after five soil gas samples were collected.

3.2.2 1600 Area

Table 3 shows the soil organic vapor (SOV) results in the 1600 Area. Benzene, toluene, ethylbenzene, and xylene (BTEX) compounds were detected in 3 of 32 locations (1628-16, 1628-17, and 1628-24) with the highest concentration being 39 µg/L. TCE or TCE degradation products (DCE and vinyl chloride) were not detected.

3.2.3 Building 1414 Area

Table 4 shows the concentrations of contaminants for the samples collected from the Building 1414 area. Contaminants were detected in 20 of 40 samples (or 16 of 35 sample locations). BTEX constituents were observed at locations 1414-21. TCE was found in the samples collected from locations 1414-04 through 1414-07, 1414-17, and 1414-20. The highest TCE concentration in the area was 15 µg/L at location 1414-06. TCE degradation products, such as vinyl chloride, trans-1,2-DCE, and cis-1,2-DCE, were detected at locations 1414-20, 1414-21, 1414-23, 1414-24, and 1414-26 with a maximum DCE concentration of 60 µg/L at location 1414-21 and a maximum vinyl chloride concentration of 33 µg/L at location 1414-23. Based on the results of the 27 soil gas samples for the locations spaced at 50-foot intervals, eight additional soil gas locations (1414-28 through 1414-35) were sampled near the locations where TCE and DCE were found. Similar concentrations of TCE and DCE were found at the additional locations along the sanitary sewer lines, except that 360 µg/L total xylenes was detected at location 1414-29. In addition, two soil gas samples were collected from outside of the sewer trench. Samples 1414-33 and 1414-34 were located about 10 feet from sanitary sewer line sample 1414-29. No contamination was detected at either location. This reinforces the assumption that soil gas contamination detected along the sanitary sewer lines is related to releases from the sewers. A total of five soil sampling locations (1414-S1 to 1414-S5) were selected at Building 1414 area adjacent to soil gas sampling locations 1414-21, 1414-29, 1414-28, 1414-23, and 1414-35 (Figure 4), respectively.

3.2.4 1100 Area

Table 5 shows soil gas analytical results in the 1100 Area near Building 1147. Contaminants

were detected in 19 of 34 sample locations. Low concentrations of BTEX (≤ 5 µg/L) were detected at locations 1147-15, 1147-30, and 1147-31. The concentrations of ethylbenzene and total xylenes at location 1147-04 were slightly higher (7 µg/L and 36 µg/L, respectively). PCE was detected in more than half of the sample locations in this area. The detected concentrations of PCE were ≤ 8 µg/L. No TCE was detected. Due to the relatively low concentrations and random nature of the soil gas results, no soil samples were collected in this area.

3.2.5 South Flight Line Area

Only PCE was detected in 12 of 29 samples (or 7 of 21 sample locations) at South Flight Line Area 2000 (Table 6). Sixteen soil gas sample locations were selected based on the locations spaced at 50-foot intervals. A PCE concentration of 17 µg/L was detected at location 2000-14. Based on the results, six additional soil gas locations were sampled near location 2000-14. Higher concentrations of PCE were found at all the additional locations with the highest PCE concentration of 46 µg/L at location 2000-18. A soil sampling location was selected adjacent to location 2000-18 as a result (Figure 6).

3.3 Soil Analysis Results

A total of ten soil samples were collected from five soil sampling locations 1414-S1 to 1414-S5. The soil sample interval depths and analytical results are shown in Table 7. Xylene was detected in 3 of the 10 soil samples at two locations (1414-S1 and 1414-S2), with the highest total xylene concentration of 0.90 mg/kg at interval depth of 7-8' on location 1414-S1. Ethylbenzene was detected in only one sample at location 1414-S2 and interval depth of 3-4' with concentration of 1.4 mg/kg. The TCE and DCE contaminants that were found in soil gas samples collected from locations 1414-21, 1414-29, 1414-28, 1414-23, and 1414-35 were not found in the soil samples.

Only one soil sample was collected from South Flight Line Area at a location adjacent to soil gas sample location 2000-18 at interval depth of 7-8'. No contaminants were detected in the soil sample (Table 8).

3.4 QA/QC Results

QA/QC results for soil gas and soil sample analysis are shown in Tables 9 and 10, respectively.

4.0 Summary and Conclusions

Past discharges of contaminants, primarily CVOCs, into leaky sanitary sewers could be one of the sources of groundwater contamination within Zone 5. A soil gas and soil sampling survey, coupled with field screening analysis, was conducted along segments of the sanitary sewers that were judged to be the most likely sources of releases.

Soil gas results are generally consistent with the groundwater contaminants for each area where contaminants were detected in soil gas. This data suggests that the sanitary sewer lines may have been the source of contamination and that contaminated soils may exist at or below these areas. This is especially true for the Building 1414 area, which had the highest levels of soil gas contaminants. However, soil samples collected in the same vicinity of the

soil gas hits did not show levels of contamination that were of concern. This does not rule out the sanitary sewers as source areas. However, it illustrates the difficulty of finding soil source sites.

It is possible that releases occurred from the sanitary sewers when the solvent still was operating at building 1414. The lack of CVOCs in the soil, and the minimal concentrations in the soil gas, could be explained by a combination of volatilization, degradation, and leaching to the groundwater. TCE releases from sanitary sewers would be particularly susceptible to degradation in that the high organic strength of sewage would create an anaerobic environment where reductive dechlorination is likely to occur in the area immediately surrounding the leak. In areas further below the sewer leak, oxygen diffusion and advection in soil gas would be expected to change the local soil environment back to aerobic conditions.

One inconsistency between soil gas and groundwater results is the absence of xylene and ethylbenzene in groundwater. Because these contaminants at the Building 1414 area are readily degradable aerobically as well as being volatile, it is likely that the low level release occurring from the sewers is being degraded and volatilized prior to reaching the water table.

No contaminated soil source sites were identified as a result of this investigation. However, soil gas data in the vicinity of Building 1414 suggest that the sanitary sewer may have been a point of release for contaminants.

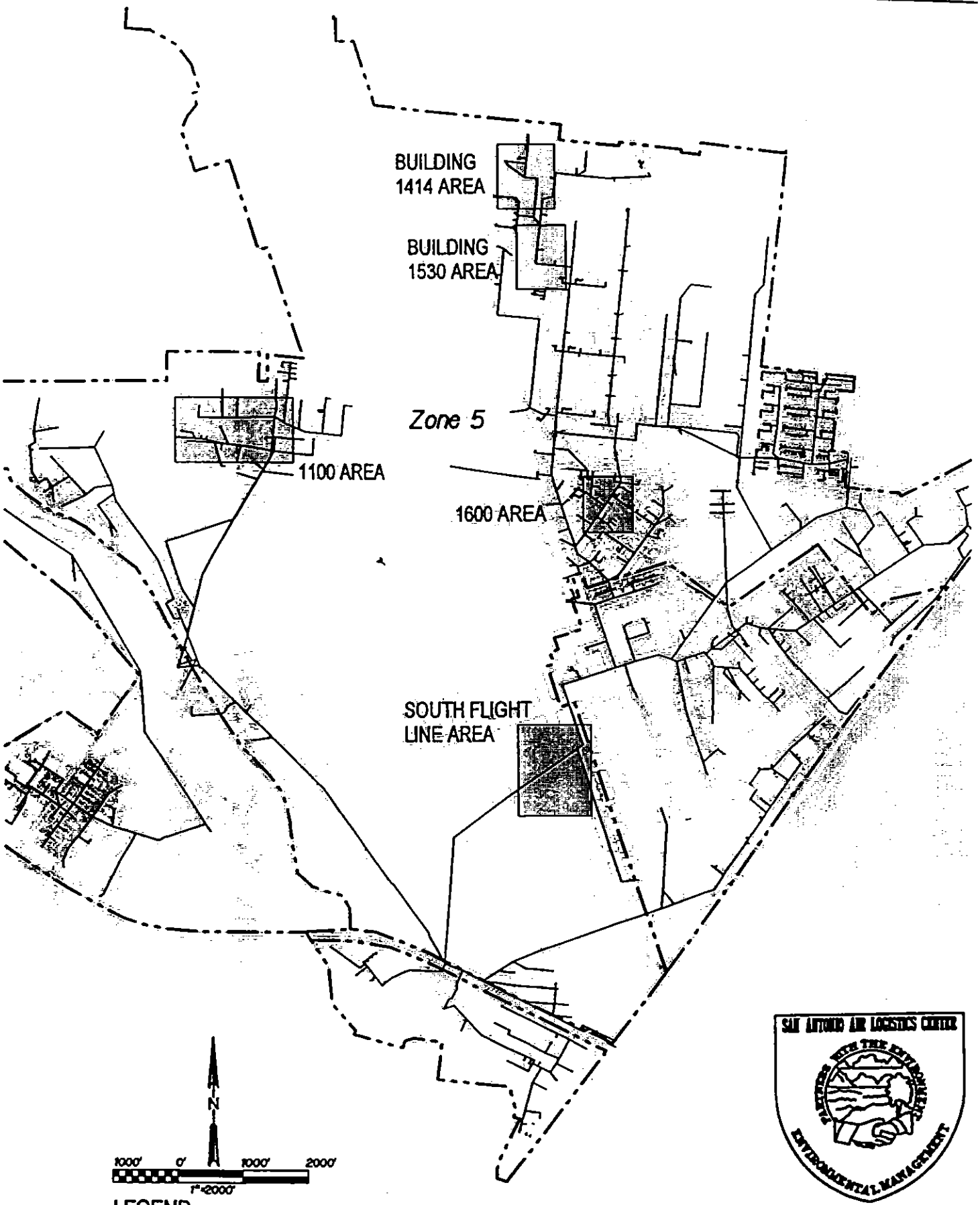
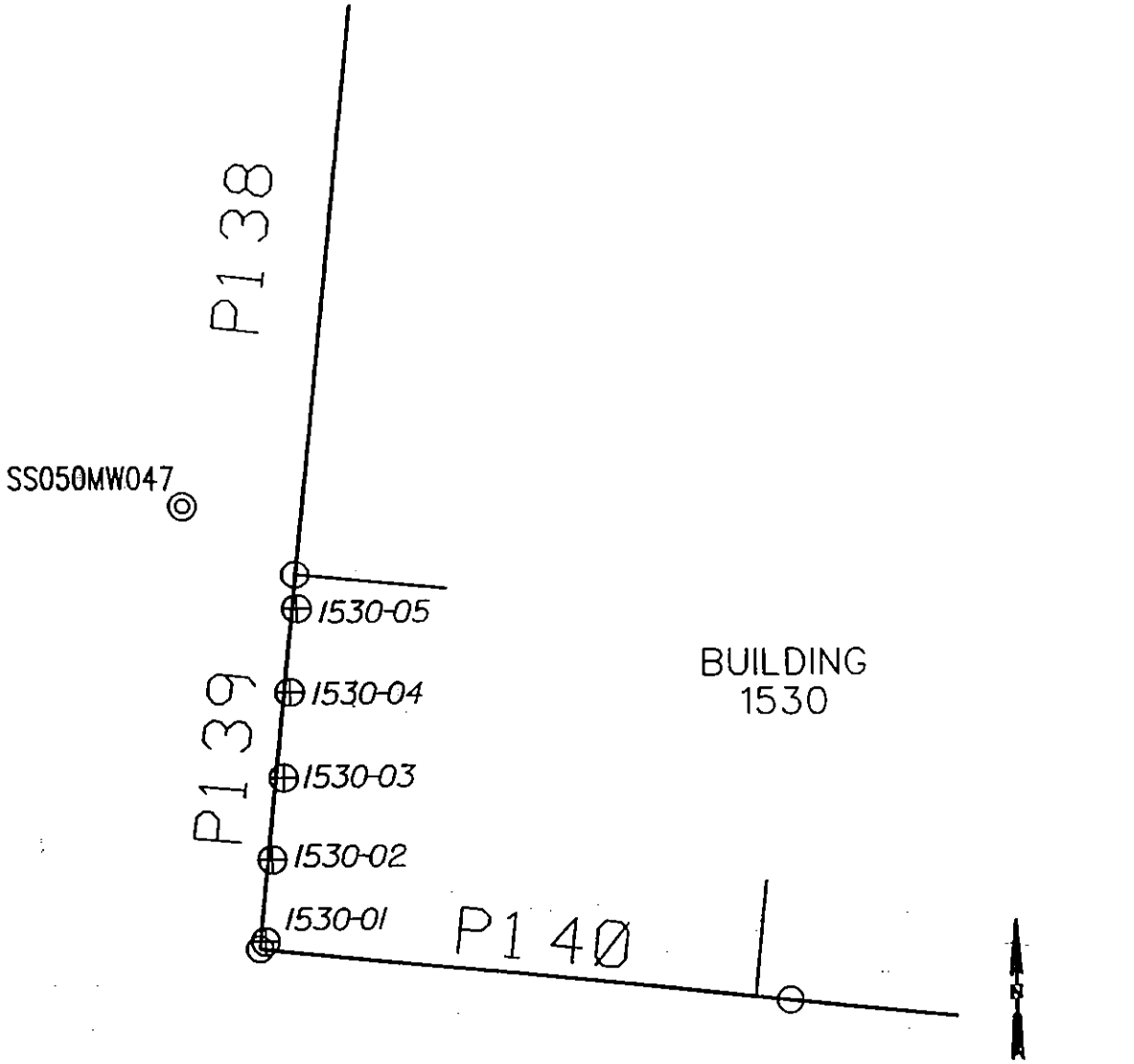


FIGURE 1
Zone 5 Sewer Line Investigation Areas
Kelly Air Force Base, Texas

CH2MHILL



LEGEND

Soil Gas Sample Locations	⊕
Soil Gas Sample Identification	1628-19
Monitoring Well	◎
Monitoring Well Identification	SS050MW047
Sanitary Sewer Line	———
Secondary Sanitary Sewer Line	- - - - - -
Manhole	○

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FIGURE 2
Soil Gas Sample Locations in
Building 1530 Area
Zone 5 Sewer Line Investigation
Kelly Air Force Base, Texas

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09-JULY-1996

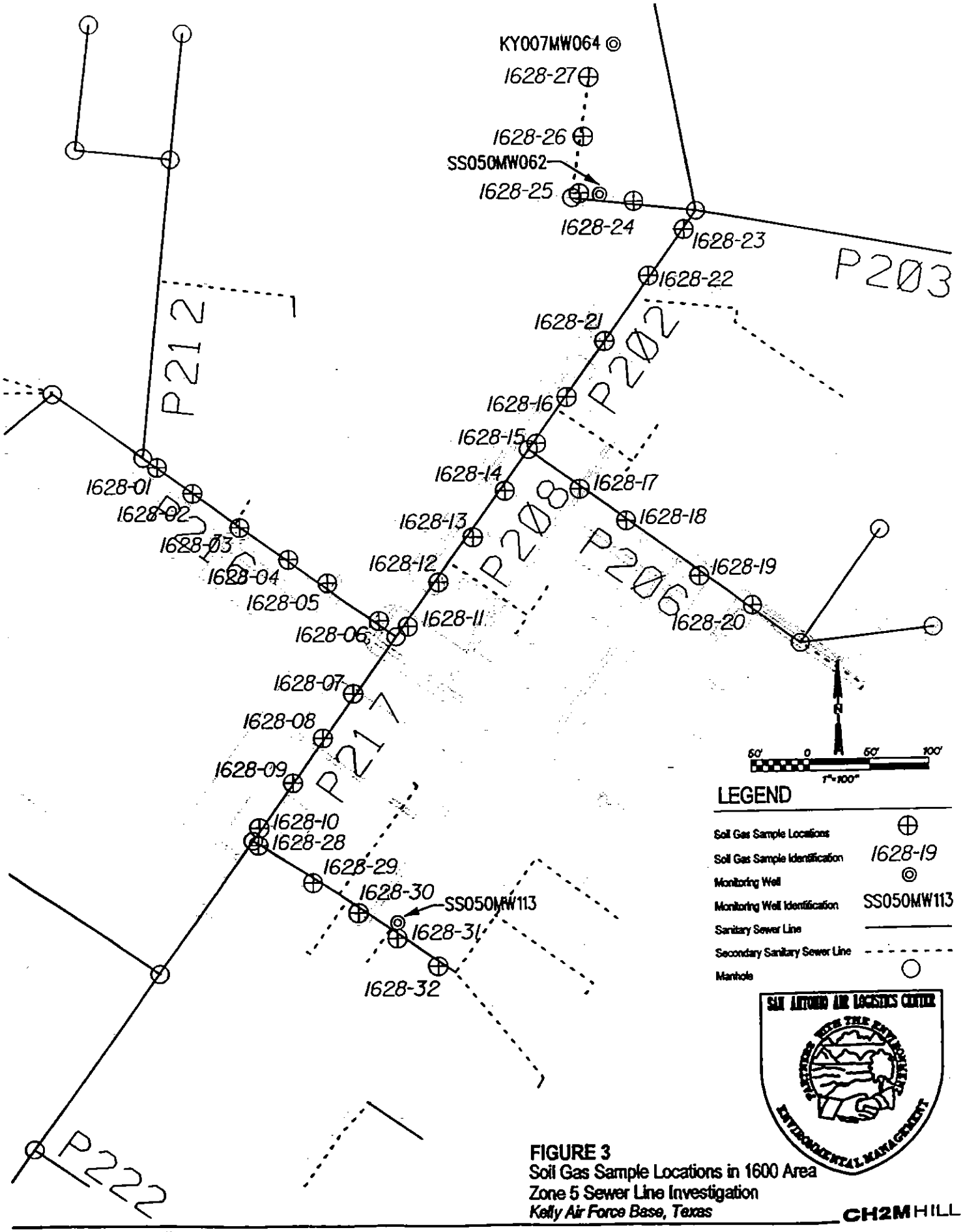

FIGURE 3
Soil Gas Sample Locations in 1600 Area
Zone 5 Sewer Line Investigation
Kelly Air Force Base, Texas

CH2M HILL

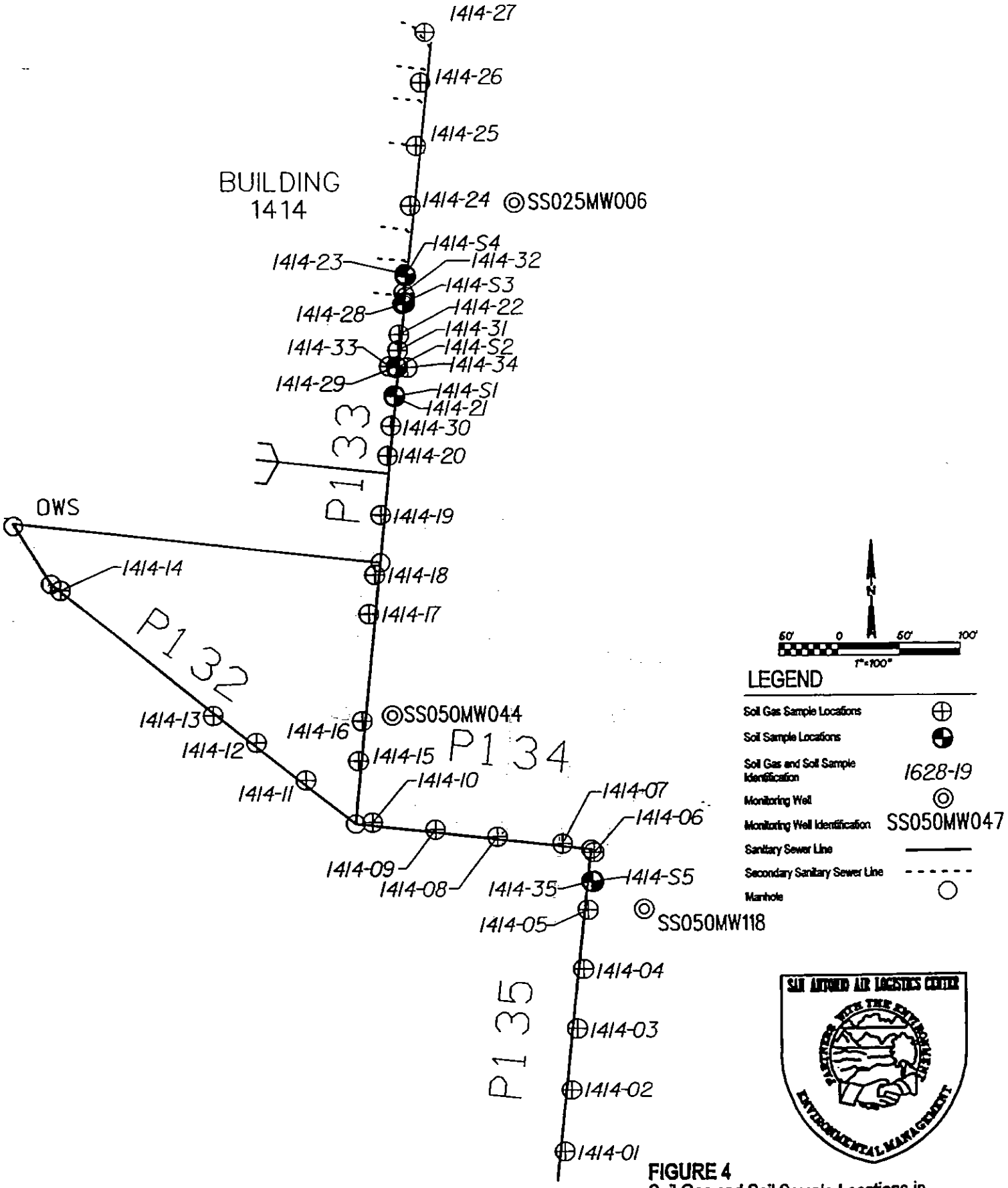

FIGURE 4
Soil Gas and Soil Sample Locations in Building 1414 Area
Zone 5 Sewer Line Investigation
Kelly Air Force Base, Texas

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SANCADKELLYIZSSEWER_INV\1194F005.DLV
09-JULY-1998

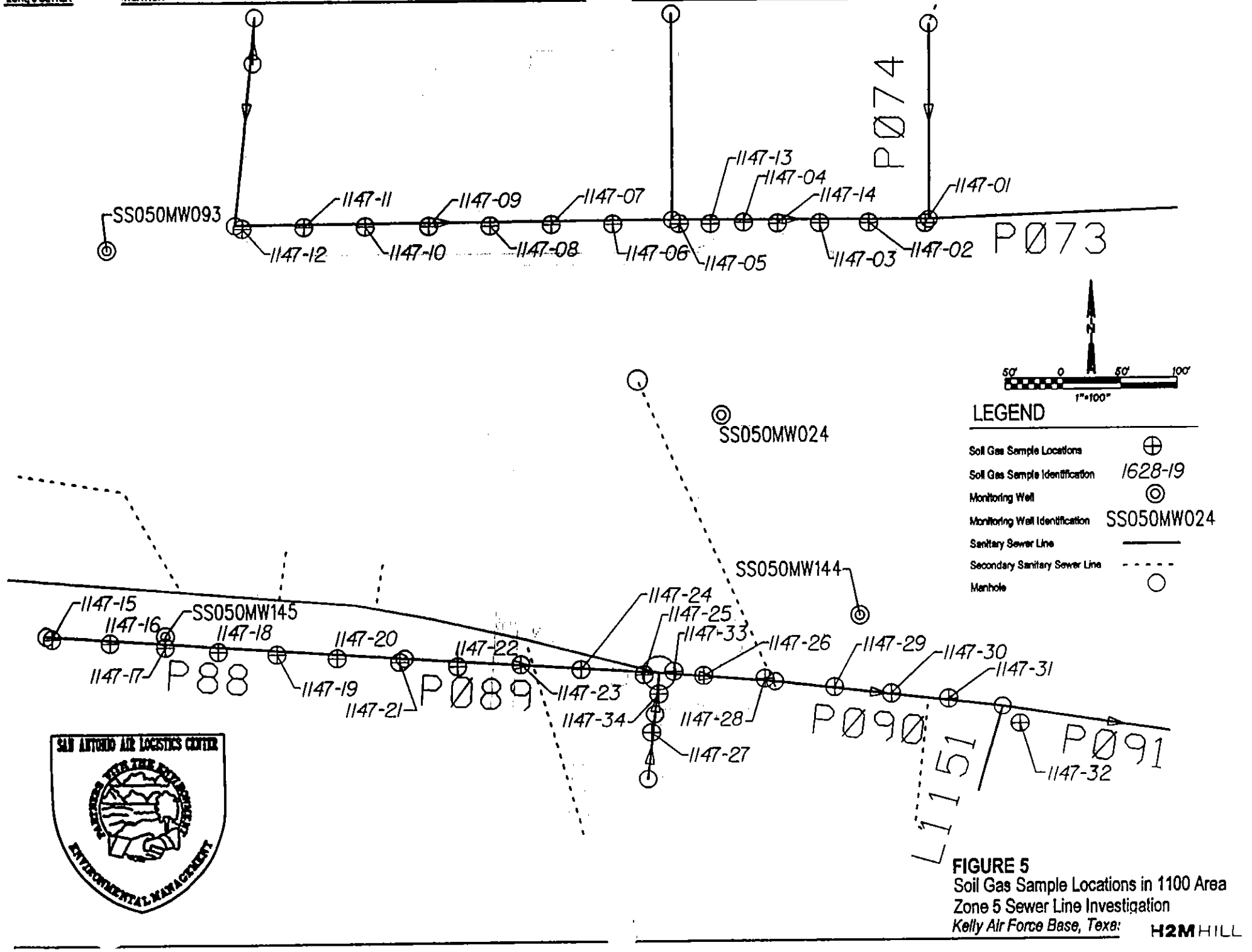

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FIGURE 5
Soil Gas Sample Locations in 1100 Area
Zone 5 Sewer Line Investigation
Kelly Air Force Base, Texas

H2M HILL

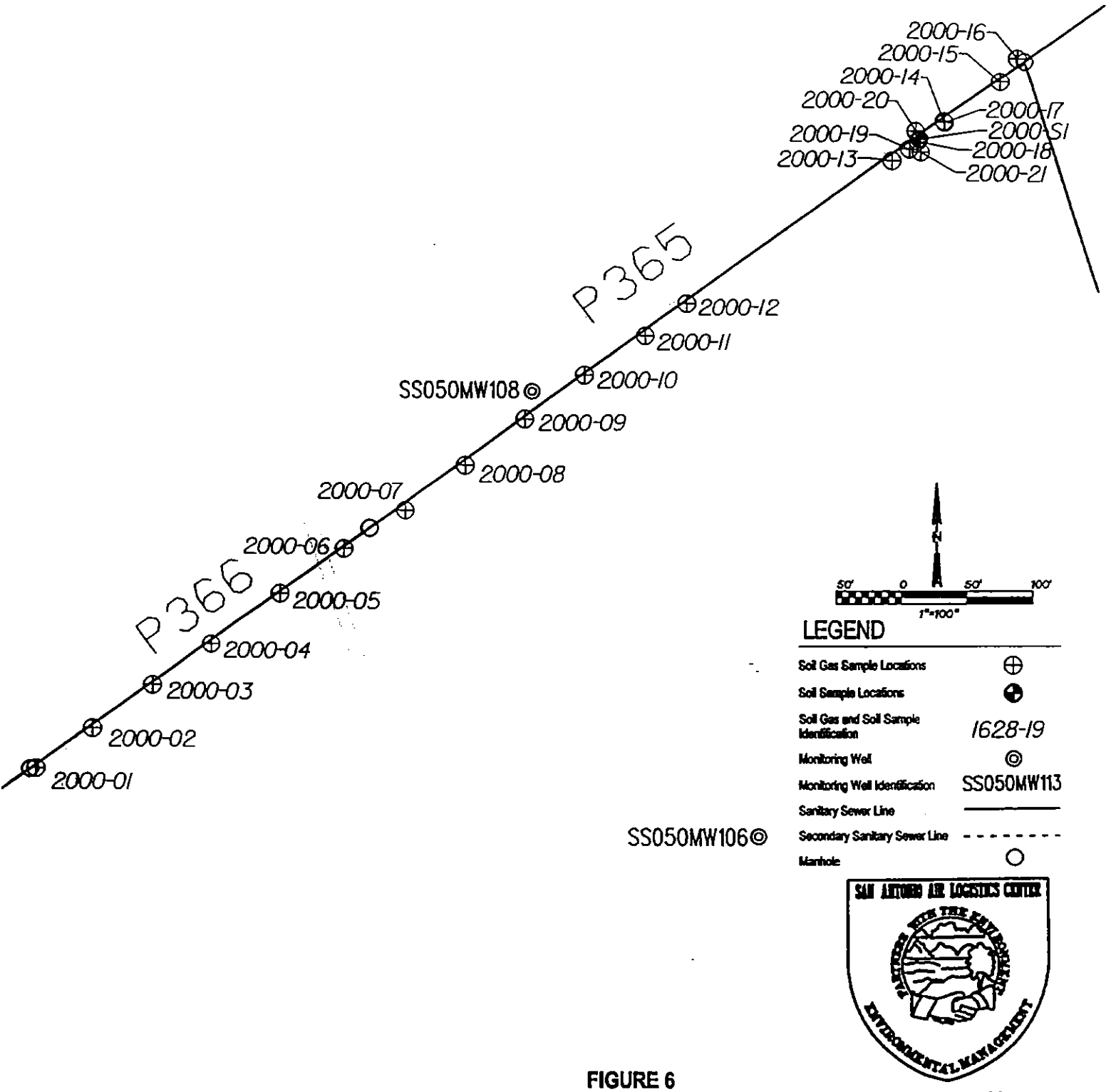

FIGURE 6
Soil Gas and Soil Sample Locations in South Flight Line Zone 5 Sewer Line Investigation
Kelly Air Force Base, Texas

CH2MHILL

SAMCAD/KELLY/ZSSEWER_INV/1194F002.DLV
09-JULY-1996

TABLE 1
Sewer Line SOV Investigation Sample Location

FIELD IDENTIFICATION	REFERENCE NUMBER	NORTHING	EASTING	ELEVATION
1147-01	3120	565265	2130936	676.9
1147-02	3119	565266	2130886	676.8
1147-03	3118	565266	2130843	677.0
1147-04	3116	565267	2130776	676.5
1147-05	3114	565266	2130720	677.4
1147-06	3113	565266	2130662	676.7
1147-07	3112	565266	2130608	676.7
1147-08	3111	565265	2130554	676.6
1147-09	3110	565265	2130500	676.5
1147-10	3109	565265	2130444	676.8
1147-11	3108	565265	2130390	677.1
1147-12	3107	565264	2130335	677.1
1147-13	3115	565266	2130747	677.3
1147-14	3117	565266	2130806	676.5
1147-15	3106	564907	2130164	676.8
1147-16	3105	564903	2130216	676.9
1147-17	3104	564899	2130265	677.1
1147-18	3103	564895	2130312	676.8
1147-19	3102	564892	2130364	676.7
1147-20	3101	564888	2130417	676.5
1147-21	3100	564884	2130472	676.6
1147-22	3099	564880	2130523	676.5
1147-23	3098	564881	2130579	676.4
1147-24	3097	564876	2130632	676.9
1147-25	3096	564871	2130687	677.2
1147-26	3092	564870	2130739	676.8
1147-27	3094	564819	2130693	676.7
1147-28	3091	564867	2130793	676.9
1147-29	3090	564859	2130854	676.8
1147-30	3089	564853	2130904	676.8
1147-31	3088	564848	2130954	676.7
1147-32	3087	564825	2131016	676.7
1147-33	3093	564874	2130713	677.1

Note: Northing and Easting based on the Texas State Plane Coordinate system within ±1.0 foot.
Elevation based on the National Geodetic Vertical Datum (NGVD) within ±0.1 foot.
*Locations for these sampling points were interpolated based on the coordinates of the adjacent sampling points.

TABLE 1 CONTD.
Sewer Line SOV Investigation Sample Location

FIELD IDENTIFICATION	REFERENCE NUMBER	NORTHING	EASTING	ELEVATION
1147-34	3095	564854	2130700	676.8
1414-01	3049	568709	2135544	693.5
1414-02	3048	568760	2135550	694.0
1414-03	3047	568810	2135555	693.9
1414-04	3046	568860	2135560	694.2
1414-05	3045	568909	2135564	694.1
1414-06	3043	568957	2135569	694.2
1414-07	3042	568964	2135544	694.0
1414-08	3041	568970	2135491	693.6
1414-09	3040	568976	2135440	693.2
1414-10	3039	568982	2135389	694.0
1414-11	3038	569017	2135336	694.1
1414-12	3037	569048	2135296	694.4
1414-13	3036	569070	2135261	694.3
1414-14	3035	569173	2135136	694.5
1414-15	3034	569033	2135378	693.7
1414-16	3033	569066	2135381	694.0
1414-17	3032	569154	2135387	694.7
1414-18	3031	569186	2135392	694.7
1414-19	3030	569235	2135397	695.7
1414-20	3029	569284	2135403	695.9
1414-21	3027	569333	2135409	696.2
1414-22	3020	569384	2135413	696.5
1414-23	3015	569434	2135418	696.3
1414-24	3014	569490	2135423	696.5
1414-25	3013	569539	2135428	696.5
1414-26	3012	569591	2135432	696.5
1414-27	3011	569633	2135436	696.3
1414-28	3019	569409	2135416	696.4
1414-29	3023	569358	2135411	696.4
1414-30	3028	569309	2135406	696.1
1414-31	3021	569371	2135412	696.5
1414-32	3017	569418	2135417	696.3
1414-33	3022	569358	2135405	696.5
1414-34	3025	569357	2135420	696.1

Note: Northing and Easting based on the Texas State Plane Coordinate system within ±1.0 foot.
Elevation based on the National Geodetic Vertical Datum (NGVD) within ±0.1 foot.
*Locations for these sampling points were interpolated based on the coordinates of the adjacent sampling points.

TABLE 1 CONTD.
Sewer Line SOV Investigation Sample Location

FIELD IDENTIFICATION	REFERENCE NUMBER	NORTHING	EASTING	ELEVATION
1414-35	3044	568933	2135567	694.2
1414-S1	3026	569334	2135409	696.2
1414-S2	3024	569357	2135411	696.4
1414-S3	3018	569410	2135417	696.3
1414-S4	3016	569433	2135419	696.3
1414-S5	*	568933	2135567	694.1
1530-01	3054	567666	2135537	693.3
1530-02	3053	567713	2135541	693.9
1530-03	3052	567760	2135548	694.0
1530-04	3051	567809	2135552	693.8
1530-05	3050	567857	2135556	693.7
1628-01	3061	564062	2136347	681.1
1628-02	3062	564040	2136377	681.2
1628-03	3063	564011	2136417	681.3
1628-04	3064	563984	2136458	681.3
1628-05	3065	563964	2136491	680.3
1628-06	3066	563932	2136534	679.6
1628-07	3067	563871	2136512	679.3
1628-08	3068	563833	2136486	679.8
1628-09	3069	563795	2136460	679.8
1628-10	3070	563757	2136431	679.8
1628-11	3060	563927	2136558	679.9
1628-12	3059	563964	2136584	679.8
1628-13	3058	564002	2136613	679.5
1628-14	3057	564041	2136640	679.5
1628-15	3056	564081	2136667	679.7
1628-16	3055	564120	2136693	679.6
1628-17	3079	564042	2136703	681.0
1628-18	3078	564015	2136742	680.5
1628-19	3077	563968	2136803	680.3
1628-20	3076	563943	2136848	680.3
1628-21	3080	564167	2136725	680.2
1628-22	3081	564222	2136763	680.3
1628-23	3082	564261	2136793	680.7
1628-24	3083	564285	2136751	680.6

Note: Northing and Easting based on the Texas State Plane Coordinate system within ±1.0 foot.
Elevation based on the National Geodetic Vertical Datum (NGVD) within ±0.1 foot.
*Locations for these sampling points were interpolated based on the coordinates of the adjacent sampling points.

TABLE 1 CONTD.
Sewer Line SOV Investigation Sample Location

FIELD IDENTIFICATION	REFERENCE NUMBER	NORTHING	EASTING	ELEVATION
1628-25	3084	564292	2136705	681.2
1628-26	3085	564340	2136709	681.6
1628-27	3086	564390	2136714	681.9
1628-28	3071	563742	2136430	679.6
1628-29	3072	563710	2136476	680.0
1628-30	3073	563684	2136514	679.8
1628-31	3074	563662	2136546	679.9
1628-32	3075	563638	2136580	679.8
2000-01	3121	559619	2135351	659.3
2000-02	3122	559650	2135394	659.1
2000-03	3123	559684	2135440	659.2
2000-04	3124	559716	2135486	659.8
2000-05	3125	559756	2135539	659.9
2000-06	3126	559791	2135588	660.5
2000-07	3127	559821	2135635	660.7
2000-08	*	559856	2135681	661.0
2000-09	3128	559891	2135727	661.2
2000-10	3129	559925	2135773	661.2
2000-11	3130	559955	2135819	662.6
2000-12	3131	559980	2135851	663.8
2000-13	3132	560092	2136009	664.9
2000-14	3138	560123	2136049	663.5
2000-15	3139	560155	2136092	662.8
2000-16	3140	560173	2136105	662.4
2000-17	3137	560122	2136050	663.6
2000-18	3135	560107	2136029	664.6
2000-19	3133	560101	2136022	664.8
2000-20	*	560115	2136027	664.6
2000-21	3134	560099	2136031	664.6
2000-S1	3136	560109	2136030	664.6

Note: Northing and Easting based on the Texas State Plane Coordinate system within ±1.0 foot.
Elevation based on the National Geodetic Vertical Datum (NGVD) within ±0.1 foot.
*Locations for these sampling points were interpolated based on the coordinates of the adjacent sampling points.

TABLE 2
SOV Investigation Results at Building 1530 Area

Sample ID	Blank	1530-01	1530-02	1530-03	1530-04	1530-05
Depth (feet)	--	7.5	6.5	6.5	6	6
Purge (cubic centimeters)	--	120	120	120	120	120
Date Analyzed	9/4/97	9/4/97	9/4/97	9/4/97	9/4/97	9/4/97
Time Analyzed	10:40	10:59	11:22	11:41	12:00	12:24
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Benzene	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND
Total Xylenes	ND	ND	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND
1,1- Dichloroethene	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND

(EPA Method 8010/8020 Modified) Analyses of vapors.
"ND" indicates not detectable or below 1.0µg/L for each analyte.
"NA" indicates not analyzed.
Analysis performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by Richard Rodriguez.

TABLE 3
SOV Investigation Results at 1600 Area

Sample ID	Blank	1628-01	1628-02	1628-03	1628-04	1628-05	1628-06	1628-07	1628-08	1628-09	1628-10
Depth (feet)	--	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Purge (cubic centimeters)	--	120	120	120	120	120	120	120	120	120	120
Date Analyzed	9/4/97	9/4/97	9/4/97	9/4/97	9/4/97	9/4/97	9/4/97	9/4/97	9/4/97	9/4/97	9/4/97
Time Analyzed	10:40	13:49	14:08	14:27	14:45	15:04	15:24	15:41	16:08	16:31	16:52
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Xylenes	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1- Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

(EPA Method 8010/8020 Modified) Analyses of vapors.
"ND" indicates not detected at or below 1.0 µg/L for each analyte.
"NA" indicates not analyzed.
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by Richard Rodriguez.

TABLE 3 CONTD.
SOV Investigation Results at 1600 Area

Sample ID	BLANK	1628-11	1628-12	1628-13	1628-14	1628-15	1628-16	1628-17	1628-18	1628-19	1628-20
Depth (feet)	--	5.5	5.5	5.5	5.5	5.5	5	5	5	5	5
Purge (cubic centimeters)	--	120	120	120	120	120	120	120	120	120	120
Date Analyzed	9/5/97	9/5/97	9/5/97	9/5/97	9/5/97	9/5/97	9/5/97	9/5/97	9/5/97	9/5/97	9/5/97
Time Analyzed	8:11	8:28	8:46	9:07	--	9:28	9:48	10:31	10:54	11:13	11:58
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Benzene	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	NA	ND	7	ND	ND	ND	ND
Total Xylenes	ND	ND	ND	ND	NA	ND	39	2	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
1,1- Dichloroethene	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethene	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND

(EPA Method 8010/8020 Modified) Analyses of vapors.
"ND" indicates not detected at or below 1.0 µg/L for each analyte.
"NA" Indicates not analyzed.
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by Richard Rodriguez.

TABLE 3 CONTD.
SOV Investigation Results at 1600 Area

Sample ID	1628-21	1628-22	1628-23	1628-24	1628-25	1628-26	1628-27
Depth (feet)	5	5	5	2	3	5	5
Purge (cubic centimeters)	120	120	120	120	120	120	120
Date Analyzed	9/5/97	9/5/97	9/5/97	9/5/97	9/5/97	9/5/97	9/5/97
Time Analyzed	11:58	12:41	13:06	13:59	14:23	14:44	15:14
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Benzene	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	4	ND	ND	ND
Total Xylenes	ND	ND	ND	30	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND	ND
1,1- Dichloroethene	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND

(EPA Method 8010/8020 Modified) Analyses of vapors.
"ND" Indicates not detected at or below 1.0 µg/L for each analyte.
"NA" Indicates not analyzed.
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by Richard Rodriguez.

TABLE 3 CONTD.
SOV Investigation Results at 1600 Area

Sample ID	BLANK	1628-28	1628-29	1628-30	1628-31	1628-32
Depth (feet)	--	5.5	5.5	5.5	5.5	5.5
Purge (cubic centimeters)	120	120	120	120	120	120
Date Analyzed	9/18/97	9/18/97	9/18/97	9/18/97	9/18/97	9/18/97
Time Analyzed	11:23	11:42	12:02	12:26	12:49	13:24
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Benzene	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND
Total Xylenes	ND	ND	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND
1,1- Dichloroethene	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND

(EPA Method 8010/8020 Modified) Analyses of vapors.
"ND" Indicates not detected at or below 1.0 µg/L for each analyte.
"NA" indicates not analyzed.
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by Richard Rodriguez.

TABLE 4
SOV Investigation Results at Building 1414 Area

Sample ID	Blank	1414-01	1414-02	1414-03	1414-04	1414-04	1414-05	1414-05	1414-06	1414-06	1414-07
Depth (feet)	--	6	6	6	2.5	6	2.5	6	2.5	6	2.5
Purge (cubic centimeter)	--	120	120	120	120	120	120	120	120	120	120
Date Analyzed	9/8/97	9/8/97	9/8/97	9/8/97	9/8/97	9/8/97	9/8/97	9/8/97	9/8/97	9/8/97	9/8/97
Time Analyzed	8:42	8:59	9:18	9:37	12:45	9:58	13:04	10:19	13:25	10:39	13:48
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Xylenes	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1- Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	2	2	2	4	5	15	1
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

(EPA Method 8010/8020 Modified) analyses of vapors.
"ND" indicates not detected at or below 1µg/L for each analyte.
"NA" indicates not analyzed.
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by: Richard Rodriguez

TABLE 4 CONTD.
SOV Investigation Results at Building 1414 Area

Sample ID	1414-07	1414-08	1414-09	1414-10	1414-11	1414-12	1414-13	1414-14	1414-15	1414-16
Depth (feet)	6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Purge (cubic centimeter)	120	120	120	120	120	120	120	120	120	120
Date Analyzed	9/8/97	9/8/97	9/8/97	9/8/97	9/8/97	9/8/97	9/8/97	9/8/97	9/8/97	9/8/97
Time Analyzed	10:59	11:25	11:45	12:25	14:06	14:22	14:41	15:03	15:23	15:43
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Xylenes	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1- Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

(EPA Method 8010/8020 Modified) analyses of vapors.
"ND" indicates not detected at or below 1µg/L for each analyte.
"NA" indicates not analyzed.
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by: Richard Rodriguez

TABLE 4 CONTD.
SOV Investigation Results at Building 1414 Area

Sample ID	BLANK	1414-17	1414-18	1414-19	1414-20	1414-21	1414-22	1414-23	1414-24	1414-25
Depth (feet)	--	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Purge (cubic centimeter)	--	120	120	120	120	120	120	120	120	120
Date Analyzed	9/9/97	9/9/97	9/9/97	9/9/97	9/9/97	9/9/97	9/9/97	9/9/97	9/9/97	9/9/97
Time Analyzed	8:44	9:50	10:10	10:34	10:58	11:22	11:55	12:19	13:18	13:42
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	2	ND	ND	ND	ND
Total Xylenes	ND	ND	ND	ND	ND	20	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	27	ND	33	ND	ND
1,1- Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	3	ND	24	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	16	60	ND	2	1	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	3	ND	ND	4	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

(EPA Method 8010/8020 Modified) analyses of vapors.
"ND" indicates not detected at or below 1µg/L for each analyte.
"NA" indicates not analyzed.
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by: Richard Rodriguez

TABLE 4 CONTD.
SOV Investigation Results at Building 1414 Area

Sample ID	1414-26	1414-27	1414-28	1414-29	1414-30	1414-31	1414-32	1414-33	1414-34	1414-35	1414-35
Depth (feet)	2.5	2.5	2.5	2.5	4	4	4	4	4	2.5	4
Purge (cubic centimeter)	120	120	120	120	120	120	120	120	120	120	120
Date Analyzed	9/9/97	9/9/97	9/9/97	9/9/97	9/11/97	9/11/97	9/11/97	9/11/97	9/11/97	9/11/97	9/11/97
Time Analyzed	14:07	14:32	14:55	15:28	15:29	15:50	16:23	16:42	17:03	17:33	17:42
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	35	70	ND	2	3	ND	ND	ND	ND
Total Xylenes	ND	ND	200	360	ND	8	15	ND	ND	ND	ND
Vinyl Chloride	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1- Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	2	ND	ND	4	ND	ND	8	10
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

(EPA Method 8010/8020 Modified) analyses of vapors.
"ND" indicates not detected at or below 1µg/L for each analyte.
"NA" Indicates not analyzed.
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by: Richard Rodriguez

Table 5
SOV Investigation Results at 1100 Area

Sample ID	BLANK	1147-01	1147-02	1147-03	1147-04	1147-05	1147-06	1147-07	1147-08	1147-09
Depth (feet)	--	7.5	7.5	7.5	7.5	7	7	6.5	6.5	6.5
Purge (cubic centimeter)	--	120	120	120	120	120	120	120	120	120
Date Analyzed	9/10/97	9/10/97	9/10/97	9/10/97	9/10/97	9/10/97	9/10/97	9/10/97	9/10/97	9/10/97
Time Analyzed	8:06	8:31	8:53	9:46	9:18	10:08	10:31	10:53	11:16	11:37
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	7	ND	ND	ND	ND	ND
Total Xylenes	ND	ND	ND	ND	36	ND	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1- Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	7	3	2	1	ND	ND
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

(EPA Method 8010/8020 Modified) Analyses of vapors.
"ND" indicates not detected at or below 1µg/L for each analyte.
"NA" indicates not analyzed.
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by: Richard Rodriguez

TABLE 5 CONTD.
SOV Investigation Results at 1100 Area

Sample ID	1147-10	1147-11	1147-12	1147-13	1147-14	1147-15	1147-16	1147-17	1147-18	1147-19
Depth (feet)	6	6	5.5	7	7	8.5	8.5	8.5	8.5	9
Purge (cubic centimeter)	120	120	120	120	120	120	120	120	120	120
Date Analyzed	9/10/97	9/10/97	9/10/97	9/10/97	9/10/97	9/10/97	9/10/97	9/10/97	9/10/97	9/11/97
Time Analyzed	11:57	12:19	13:02	13:24	14:01	14:23	14:44	15:07	15:33	10:31
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Xylenes	ND	ND	ND	ND	ND	5	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1- Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	3	2	ND	ND	ND	ND	1
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

(EPA Method 8010/8020 Modified) Analyses of vapors.
"ND" indicates not detected at or below 1µg/L for each analyte.
"NA" indicates not analyzed.
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by: Richard Rodriguez

TABLE 5 CONTD.
SOV Investigation Results at 1100 Area

Sample ID	1147-20	1147-21	1147-22	1147-23	BLANK	1147-24	1147-25	1147-26	1147-27	1147-28
Depth (feet)	9	9.5	10	10	--	11	11	11	4	11
Purge (cubic centimeter)	120	120	120	120	--	120	120	120	120	120
Date Analyzed	9/10/97	9/10/97	9/10/97	9/10/97	9/11/97	9/11/97	9/11/97	9/11/97	9/11/97	9/11/97
Time Analyzed	15:55	16:17	16:38	17:02	8:31	8:56	9:18	9:42	10:05	10:51
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Xylenes	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1- Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	3	1	ND	5	ND	2	1	8	4	ND
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

(EPA Method 8010/8020 Modified) Analyses of vapors.
"ND" indicates not detected at or below 1µg/L for each analyte.
"NA" indicates not analyzed.
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by: Richard Rodriguez

TABLE 5 CONTD.
SOV Investigation Results at 1100 Area

Sample ID	1147-29	1147-30	1147-31	1147-32	1147-33	1147-34
Depth (feet)	11	11	11	11	11	11
Purge (cubic centimeter)	120	120	120	120	120	120
Date Analyzed	9/11/97	9/11/97	9/11/97	9/11/97	9/11/97	9/11/97
Time Analyzed	11:11	11:32	12:05	12:41	14:20	14:41
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Benzene	ND	1	1	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND
Total Xylenes	ND	5	3	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND
1,1- Dichloroethene	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	3	3
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND

(EPA Method 8010/8020 Modified) Analyses of vapors.
"ND" indicates not detected at or below 1µg/L for each analyte.
"NA" Indicates not analyzed.
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by: Richard Rodriguez

TABLE 6
SOV Investigation Results at Flight Line Area 2000

Sample ID	BLANK	2000-01	2000-02	2000-03	2000-04	2000-05	2000-05	2000-06	2000-06	2000-07	2000-07
Depth (feet)	--	3.5	3.5	3.5	3.5	3.5	5.5	3.5	5.5	3.5	5.5
Purge (cubic centimeter)	--	120	120	120	120	120	120	120	120	120	120
Date Analyzed	9/12/97	9/12/97	9/12/97	9/12/97	9/12/97	9/15/97	9/15/97	9/15/97	9/15/97	9/15/97	9/15/97
Time Analyzed	10:30	10:46	11:08	11:33	11:53	13:27	13:52	14:16	14:37	14:57	15:17
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Xylenes	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1- Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

(EPA Method 8010/8020 Modified) analyses of vapors.
"ND" indicates not detected at or below 1µg/L for each analyte.
"NA" indicates not analyzed.
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by: Richard Rodriguez

TABLE 6 CONTD.
SOV Investigation Results at Flight Line Area 2000

Sample ID	2000-08	2000-09	2000-10	2000-11	2000-12	BLANK	2000-13	2000-14	2000-15	2000-16
Depth (feet)	4	4	4	4	4	--	4	4	3.5	3.5
Purge (cubic centimeter)	120	120	120	120	120	--	120	120	120	120
Date Analyzed	9/12/97	9/12/97	9/12/97	9/12/97	9/12/97	9/15/97	9/15/97	9/15/97	9/15/97	9/15/97
Time Analyzed	12:13	12:36	12:59	13:20	13:41	8:06	8:57	9:19	9:42	10:06
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Xylenes	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1- Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	17	1	ND
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

(EPA Method 8010/8020 Modified) analyses of vapors.
"ND" indicates not detected at or below 1µg/L for each analyte.
"NA" indicates not analyzed.
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by: Richard Rodriguez

TABLE 6 CONTD.
SOV Investigation Results at Flight Line Area 2000

Sample ID	2000-17	2000-18	2000-18	BLANK	2000-19	2000-19	2000-20	2000-20	2000-21	2000-21	2000-21
Depth (cubic centimeter)	5.5	4	5.5	--	4	5.5	4	5.5	4	5.5	8
Purge (cubic centimeter)	120	120	120	--	120	120	120	120	120	120	120
Date Analyzed	9/15/97	9/15/97	9/15/97	9/17/97	9/17/97	9/17/97	9/17/97	9/17/97	9/17/97	9/17/97	9/17/97
Time Analyzed	11:22	12:13	12:38	12:53	13:16	13:39	14:05	14:30	14:53	15:16	15:43
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Xylenes	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1- Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	18	20	46	ND	34	37	25	32	24	30	34
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

(EPA Method 8010/8020 Modified) analyses of vapors.
"ND" indicates not detected at or below 1µg/L for each analyte.
"NA" indicates not analyzed.
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by: Richard Rodriguez

TABLE 7
Soil Investigation Results at Building 1414 Area

SAMPLE ID	BLANK	1414-S1	1414-S1	1414-S1	1414-S2	1414-S3	1414-S3	1414-S4	1414-S4	BLANK	1414-S5	1414-S5
DEPTH (FT)	--	5-6	3-4	7-8	3-4	4-6	8-10	0-2	14-16	--	5-6	9-10
DATE ANALYZED	9/16/97	9/16/97	9/16/97	9/16/97	9/16/97	9/16/97	9/16/97	9/16/97	9/16/97	9/17/97	9/17/97	9/17/97
TIME ANALYZED	9:17	9:42	10:33	11:57	12:21	14:20	14:46	16:16	16:40	7:35	9:22	9:47
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	1.40	ND	ND	ND	ND	ND	ND	ND
Total Xylenes	ND	0.15	ND	0.90	0.35	ND	ND	ND	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1- Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
% Surrogate Recovery	89	91	82	93	81	84	90	72	87	89	88	88

(EPA Method 8010/8020 Modified) analyses of soils.
"ND" Indicates not detected at or below 0.05mg/kg for each analyte.
"NA" Indicates not analyzed.
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by: Richard Rodriguez

TABLE 8

Soil Investigation Results at Flight Line Area 2000

Sample ID	2000-S1
Depth (feet)	7-8'
Date Analyzed	9/17/97
Time Analyzed	11:49
	mg/kg
Benzene	ND
Toluene	ND
Ethylbenzene	ND
Total Xylenes	ND
Vinyl Chloride	ND
1,1- Dichloroethene	ND
Methylene Chloride	ND
Trans-1,2-Dichloroethene	ND
1,1-Dichloroethane	ND
Cis-1,2-Dichloroethene	ND
Chloroform	ND
1,1,1-Trichloroethane	ND
Carbon Tetrachloride	ND
1,2-Dichloroethane	ND
Trichloroethene	ND
1,1,2-Trichloroethane	ND
Tetrachloroethene	ND
1,1,1,2-Tetrachloroethane	ND
1,1,2,2-Tetrachloroethane	ND
% Surrogate Recovery	80

(EPA Method 8010/8020 Modified) analyses of soils.
"ND" indicates not detected at or below 0.05mg/kg for each analyte.
"NA" indicates not analyzed.
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses performed by: Richard Rodriguez

TABLE 9
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/4/97 Time: 9:54				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	12.11	121
Toluene	10.00	ng/µL	11.68	117
Ethylbenzene	10.00	ng/µL	11.57	116
Total Xylenes	30.00	ng/µL	33.56	112
1,1- Dichloroethene	10.00	ng/µL	11.31	113
Vinyl Chloride	10.00	ng/µL	10.05	101
Methylene chloride	10.00	ng/µL	9.49	95
Trans-1,2-dichloroethene	10.00	ng/µL	10.10	101
1,1-Dichloroethane	10.00	ng/µL	10.22	102
Cis-1,2-Dichloroethene	10.00	ng/µL	10.68	107
Chloroform	10.00	ng/µL	10.73	107
1,1,1-Trichloroethane	10.00	ng/µL	10.32	103
Carbon Tetrachloride	10.00	ng/µL	10.71	107
1,2-Dichloroethane	10.00	ng/µL	10.28	103
Trichloroethene	10.00	ng/µL	10.29	103
1,1,2-Trichloroethane	10.00	ng/µL	9.83	98
Tetrachloroethene	10.00	ng/µL	11.82	118
1,1,1,2-Tetrachloroethane	10.00	ng/µL	12.38	124
1,1,2,2-tetrachloroethane	10.00	ng/µL	10.42	104

Date:9/4/97 Time: 13:01				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	11.78	118
Toluene	10.00	ng/µL	11.66	117
Ethylbenzene	10.00	ng/µL	10.97	110
Total Xylenes	30.00	ng/µL	31.58	105
1,1- Dichloroethene	10.00	ng/µL	10.89	109
Vinyl Chloride	10.00	ng/µL	9.07	91
Methylene chloride	10.00	ng/µL	10.41	104
Trans-1,2-dichloroethene	10.00	ng/µL	11.71	117
1,1-Dichloroethane	10.00	ng/µL	11.36	114
Cis-1,2-Dichloroethene	10.00	ng/µL	10.39	104
Chloroform	10.00	ng/µL	11.28	113
1,1,1-Trichloroethane	10.00	ng/µL	11.19	112
Carbon Tetrachloride	10.00	ng/µL	11.10	111
1,2-Dichloroethane	10.00	ng/µL	9.53	95
Trichloroethene	10.00	ng/µL	10.92	109
1,1,2-Trichloroethane	10.00	ng/µL	10.78	108
Tetrachloroethene	10.00	ng/µL	11.10	111
1,1,1,2-Tetrachloroethane	10.00	ng/µL	12.94	129
1,1,2,2-tetrachloroethane	10.00	ng/µL	10.26	103

TABLE 9 CONTD.
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/4/97 Time: 17:10				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	11.36	114
Toluene	10.00	ng/µL	11.80	118
Ethylbenzene	10.00	ng/µL	11.58	116
Total Xylenes	30.00	ng/µL	33.67	112
1,1- Dichloroethene	10.00	ng/µL	9.99	100
Vinyl Chloride	10.00	ng/µL	9.47	95
Methylene chloride	10.00	ng/µL	9.89	99
Trans-1,2-dichloroethene	10.00	ng/µL	10.79	108
1,1-Dichloroethane	10.00	ng/µL	11.20	112
Cis-1,2-Dichloroethene	10.00	ng/µL	11.11	111
Chloroform	10.00	ng/µL	11.67	117
1,1,1-Trichloroethane	10.00	ng/µL	11.46	115
Carbon Tetrachloride	10.00	ng/µL	11.89	119
1,2-Dichloroethane	10.00	ng/µL	10.94	109
Trichloroethene	10.00	ng/µL	11.55	116
1,1,2-Trichloroethane	10.00	ng/µL	10.76	108
Tetrachloroethene	10.00	ng/µL	12.38	124
1,1,1,2-Tetrachloroethane	10.00	ng/µL	13.70	137
1,1,2,2-tetrachloroethane	10.00	ng/µL	11.07	111

% Recovery – Percent recovery of analyte(s) from standard
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory
Analyses performed by: Richard Rodriguez

TABLE 9 CONTD.
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/5/97 Time: 7:29				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	10.53	105
Toluene	10.00	ng/µL	10.52	105
Ethylbenzene	10.00	ng/µL	10.32	103
Total Xylenes	30.00	ng/µL	30.19	101
1,1- Dichloroethene	10.00	ng/µL	11.15	112
Vinyl Chloride	10.00	ng/µL	10.70	107
Methylene chloride	10.00	ng/µL	8.59	86
Trans-1,2-dichloroethene	10.00	ng/µL	9.82	98
1,1-Dichloroethane	10.00	ng/µL	10.16	102
Cis-1,2-Dichloroethene	10.00	ng/µL	9.67	97
Chloroform	10.00	ng/µL	9.42	94
1,1,1-Trichloroethane	10.00	ng/µL	8.74	87
Carbon Tetrachloride	10.00	ng/µL	9.30	93
1,2-Dichloroethane	10.00	ng/µL	10.08	101
Trichloroethene	10.00	ng/µL	8.90	89
1,1,2-Trichloroethane	10.00	ng/µL	8.29	83
Tetrachloroethene	10.00	ng/µL	9.01	90
1,1,1,2-Tetrachloroethane	10.00	ng/µL	9.58	96
1,1,2,2-tetrachloroethane	10.00	ng/µL	8.97	90

Date:9/5/97 Time: 12:20				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	10.61	106
Toluene	10.00	ng/µL	9.67	97
Ethylbenzene	10.00	ng/µL	10.53	105
Total Xylenes	30.00	ng/µL	30.70	102
1,1- Dichloroethene	10.00	ng/µL	10.17	102
Vinyl Chloride	10.00	ng/µL	8.12	81
Methylene chloride	10.00	ng/µL	9.88	99
Trans-1,2-dichloroethene	10.00	ng/µL	11.26	113
1,1-Dichloroethane	10.00	ng/µL	10.27	103
Cis-1,2-Dichloroethene	10.00	ng/µL	9.94	99
Chloroform	10.00	ng/µL	9.85	99
1,1,1-Trichloroethane	10.00	ng/µL	9.62	96
Carbon Tetrachloride	10.00	ng/µL	9.87	99
1,2-Dichloroethane	10.00	ng/µL	10.60	106
Trichloroethene	10.00	ng/µL	9.03	90
1,1,2-Trichloroethane	10.00	ng/µL	9.35	94
Tetrachloroethene	10.00	ng/µL	10.44	104
1,1,1,2-Tetrachloroethane	10.00	ng/µL	10.60	106
1,1,2,2-tetrachloroethane	10.00	ng/µL	9.59	96

TABLE 9 CONTD.
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/5/97 Time: 15:32				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	9.17	92
Toluene	10.00	ng/µL	9.08	91
Ethylbenzene	10.00	ng/µL	9.62	96
Total Xylenes	30.00	ng/µL	27.68	92
1,1- Dichloroethene	10.00	ng/µL	8.93	89
Vinyl Chloride	10.00	ng/µL	8.63	86
Methylene chloride	10.00	ng/µL	9.86	99
Trans-1,2-dichloroethene	10.00	ng/µL	9.97	100
1,1-Dichloroethane	10.00	ng/µL	10.98	110
Cis-1,2-Dichloroethene	10.00	ng/µL	10.98	110
Chloroform	10.00	ng/µL	9.37	94
1,1,1-Trichloroethane	10.00	ng/µL	10.18	102
Carbon Tetrachloride	10.00	ng/µL	10.58	106
1,2-Dichloroethane	10.00	ng/µL	10.32	103
Trichloroethene	10.00	ng/µL	10.48	105
1,1,2-Trichloroethane	10.00	ng/µL	10.36	104
Tetrachloroethene	10.00	ng/µL	9.50	95
1,1,1,2-Tetrachloroethane	10.00	ng/µL	11.67	117
1,1,2,2-tetrachloroethane	10.00	ng/µL	11.31	113

% Recovery – Percent recovery of analyte(s) from standard
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory
Analyses performed by: Richard Rodriguez

TABLE 9 CONTD.
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/8/97 Time: 8:17				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	11.72	117
Toluene	10.00	ng/µL	10.94	109
Ethylbenzene	10.00	ng/µL	11.21	112
Total Xylenes	30.00	ng/µL	33.10	110
1,1- Dichloroethene	10.00	ng/µL	10.76	108
Vinyl Chloride	10.00	ng/µL	11.46	115
Methylene chloride	10.00	ng/µL	8.57	86
Trans-1,2-dichloroethene	10.00	ng/µL	9.48	95
1,1-Dichloroethane	10.00	ng/µL	9.23	92
Cis-1,2-Dichloroethene	10.00	ng/µL	9.14	91
Chloroform	10.00	ng/µL	9.49	95
1,1,1-Trichloroethane	10.00	ng/µL	9.13	91
Carbon Tetrachloride	10.00	ng/µL	9.47	95
1,2-Dichloroethane	10.00	ng/µL	9.62	96
Trichloroethene	10.00	ng/µL	9.29	93
1,1,2-Trichloroethane	10.00	ng/µL	8.69	87
Tetrachloroethene	10.00	ng/µL	10.35	104
1,1,1,2-Tetrachloroethane	10.00	ng/µL	11.65	117
1,1,2,2-tetrachloroethane	10.00	ng/µL	9.62	96

Date:9/8/97 Time: 12:02				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	10.35	104
Toluene	10.00	ng/µL	10.38	104
Ethylbenzene	10.00	ng/µL	10.59	106
Total Xylenes	30.00	ng/µL	30.80	103
1,1- Dichloroethene	10.00	ng/µL	9.86	99
Vinyl Chloride	10.00	ng/µL	8.51	85
Methylene chloride	10.00	ng/µL	10.22	102
Trans-1,2-dichloroethene	10.00	ng/µL	10.20	102
1,1-Dichloroethane	10.00	ng/µL	11.36	114
Cis-1,2-Dichloroethene	10.00	ng/µL	10.99	110
Chloroform	10.00	ng/µL	10.89	109
1,1,1-Trichloroethane	10.00	ng/µL	11.12	111
Carbon Tetrachloride	10.00	ng/µL	10.69	107
1,2-Dichloroethane	10.00	ng/µL	11.13	111
Trichloroethene	10.00	ng/µL	10.44	104
1,1,2-Trichloroethane	10.00	ng/µL	10.75	108
Tetrachloroethene	10.00	ng/µL	11.54	115
1,1,1,2-Tetrachloroethane	10.00	ng/µL	11.46	115
1,1,2,2-tetrachloroethane	10.00	ng/µL	11.10	111

TABLE 9 CONTD.
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/8/97 Time: 16:02				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	9.55	96
Toluene	10.00	ng/µL	9.11	91
Ethylbenzene	10.00	ng/µL	9.79	98
Total Xylenes	30.00	ng/µL	28.60	95
1,1- Dichloroethene	10.00	ng/µL	9.01	90
Vinyl Chloride	10.00	ng/µL	8.15	82
Methylene chloride	10.00	ng/µL	11.34	113
Trans-1,2-dichloroethene	10.00	ng/µL	11.45	115
1,1-Dichloroethane	10.00	ng/µL	10.81	108
Cis-1,2-Dichloroethene	10.00	ng/µL	11.35	114
Chloroform	10.00	ng/µL	11.08	111
1,1,1-Trichloroethane	10.00	ng/µL	10.97	110
Carbon Tetrachloride	10.00	ng/µL	11.11	111
1,2-Dichloroethane	10.00	ng/µL	10.16	102
Trichloroethene	10.00	ng/µL	10.55	106
1,1,2-Trichloroethane	10.00	ng/µL	11.52	115
Tetrachloroethene	10.00	ng/µL	11.22	112
1,1,1,2-Tetrachloroethane	10.00	ng/µL	12.75	128
1,1,2,2-tetrachloroethane	10.00	Ng/µL	11.00	110

% Recovery – Percent recovery of analyte(s) from standard
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory
Analyses performed by: Richard Rodriguez

TABLE 9 CONTD.
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/9/97 Time: 7:56				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	10.07	101
Toluene	10.00	ng/µL	9.85	99
Ethylbenzene	10.00	ng/µL	10.47	105
Total Xylenes	30.00	ng/µL	29.89	100
1,1- Dichloroethene	10.00	ng/µL	9.32	93
Vinyl Chloride	10.00	ng/µL	8.03	80
Methylene chloride	10.00	ng/µL	10.17	102
Trans-1,2-dichloroethene	10.00	ng/µL	10.09	101
1,1-Dichloroethane	10.00	ng/µL	10.41	104
Cis-1,2-Dichloroethene	10.00	ng/µL	10.48	105
Chloroform	10.00	ng/µL	12.18	122
1,1,1-Trichloroethane	10.00	ng/µL	9.44	94
Carbon Tetrachloride	10.00	ng/µL	10.64	106
1,2-Dichloroethane	10.00	ng/µL	10.41	104
Trichloroethene	10.00	ng/µL	9.77	98
1,1,2-Trichloroethane	10.00	ng/µL	12.68	127
Tetrachloroethene	10.00	ng/µL	9.48	95
1,1,1,2-Tetrachloroethane	10.00	ng/µL	11.02	110
1,1,2,2-tetrachloroethane	10.00	ng/µL	10.81	108

Date:9/9/97 Time: 12:48				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	9.52	95
Toluene	10.00	ng/µL	9.36	94
Ethylbenzene	10.00	ng/µL	9.78	98
Total Xylenes	30.00	ng/µL	28.65	96
1,1- Dichloroethene	10.00	ng/µL	8.78	88
Vinyl Chloride	10.00	ng/µL	8.63	86
Methylene chloride	10.00	ng/µL	10.50	105
Trans-1,2-dichloroethene	10.00	ng/µL	9.41	94
1,1-Dichloroethane	10.00	ng/µL	10.92	109
Cis-1,2-Dichloroethene	10.00	ng/µL	9.63	96
Chloroform	10.00	ng/µL	12.92	129
1,1,1-Trichloroethane	10.00	ng/µL	10.89	109
Carbon Tetrachloride	10.00	ng/µL	11.14	111
1,2-Dichloroethane	10.00	ng/µL	10.45	105
Trichloroethene	10.00	ng/µL	9.62	96
1,1,2-Trichloroethane	10.00	ng/µL	13.61	136
Tetrachloroethene	10.00	ng/µL	9.41	94
1,1,1,2-Tetrachloroethane	10.00	ng/µL	11.44	114
1,1,2,2-tetrachloroethane	10.00	ng/µL	13.12	131

TABLE 9 CONTD.
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/9/97 Time: 15:52				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	8.90	89
Toluene	10.00	ng/µL	8.60	86
Ethylbenzene	10.00	ng/µL	8.93	89
Total Xylenes	30.00	ng/µL	26.33	88
1,1- Dichloroethene	10.00	ng/µL	8.22	82
Vinyl Chloride	10.00	ng/µL	7.20	72
Methylene chloride	10.00	ng/µL	10.42	104
Trans-1,2-dichloroethene	10.00	ng/µL	8.62	86
1,1-Dichloroethane	10.00	ng/µL	11.17	112
Cis-1,2-Dichloroethene	10.00	ng/µL	8.87	89
Chloroform	10.00	ng/µL	13.34	133
1,1,1-Trichloroethane	10.00	ng/µL	10.94	109
Carbon Tetrachloride	10.00	ng/µL	11.15	112
1,2-Dichloroethane	10.00	ng/µL	11.30	113
Trichloroethene	10.00	ng/µL	8.90	89
1,1,2-Trichloroethane	10.00	ng/µL	12.17	122
Tetrachloroethene	10.00	ng/µL	9.30	93
1,1,1,2-Tetrachloroethane	10.00	ng/µL	11.69	117
1,1,2,2-tetrachloroethane	10.00	ng/µL	12.27	123

% Recovery – Percent recovery of analyte(s) from standard
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory
Analyses performed by: Richard Rodriguez

TABLE 9 CONTD.
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/9/97 Time: 7:56				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	10.07	101
Toluene	10.00	ng/µL	9.85	99
Ethylbenzene	10.00	ng/µL	10.47	105
Total Xylenes	30.00	ng/µL	29.89	100
1,1- Dichloroethene	10.00	ng/µL	9.32	93
Vinyl Chloride	10.00	ng/µL	8.03	80
Methylene chloride	10.00	ng/µL	10.17	102
Trans-1,2-dichloroethene	10.00	ng/µL	10.09	101
1,1-Dichloroethane	10.00	ng/µL	10.41	104
Cis-1,2-Dichloroethene	10.00	ng/µL	10.48	105
Chloroform	10.00	ng/µL	12.18	122
1,1,1-Trichloroethane	10.00	ng/µL	9.44	94
Carbon Tetrachloride	10.00	ng/µL	10.64	106
1,2-Dichloroethane	10.00	ng/µL	10.41	104
Trichloroethene	10.00	ng/µL	9.77	98
1,1,2-Trichloroethane	10.00	ng/µL	12.68	127
Tetrachloroethene	10.00	ng/µL	9.48	95
1,1,1,2-Tetrachloroethane	10.00	ng/µL	11.02	110
1,1,2,2-tetrachloroethane	10.00	ng/µL	10.81	108

Date:9/9/97 Time: 12:48				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	9.52	95
Toluene	10.00	ng/µL	9.36	94
Ethylbenzene	10.00	ng/µL	9.78	98
Total Xylenes	30.00	ng/µL	28.65	96
1,1- Dichloroethene	10.00	ng/µL	8.78	88
Vinyl Chloride	10.00	ng/µL	8.63	86
Methylene chloride	10.00	ng/µL	10.50	105
Trans-1,2-dichloroethene	10.00	ng/µL	9.41	94
1,1-Dichloroethane	10.00	ng/µL	10.92	109
Cis-1,2-Dichloroethene	10.00	ng/µL	9.63	96
Chloroform	10.00	ng/µL	12.92	129
1,1,1-Trichloroethane	10.00	ng/µL	10.89	109
Carbon Tetrachloride	10.00	ng/µL	11.14	111
1,2-Dichloroethane	10.00	ng/µL	10.45	105
Trichloroethene	10.00	ng/µL	9.62	96
1,1,2-Trichloroethane	10.00	ng/µL	13.61	136
Tetrachloroethene	10.00	ng/µL	9.41	94
1,1,1,2-Tetrachloroethane	10.00	ng/µL	11.44	114
1,1,2,2-tetrachloroethane	10.00	ng/µL	13.12	131

TABLE 9 CONTD.
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/9/97 Time: 15:52				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	8.90	89
Toluene	10.00	ng/µL	8.60	86
Ethylbenzene	10.00	ng/µL	8.93	89
Total Xylenes	30.00	ng/µL	26.33	88
1,1- Dichloroethene	10.00	ng/µL	8.22	82
Vinyl Chloride	10.00	ng/µL	7.20	72
Methylene chloride	10.00	ng/µL	10.42	104
Trans-1,2-dichloroethene	10.00	ng/µL	8.62	86
1,1-Dichloroethane	10.00	ng/µL	11.17	112
Cis-1,2-Dichloroethene	10.00	ng/µL	8.87	89
Chloroform	10.00	ng/µL	13.34	133
1,1,1-Trichloroethane	10.00	ng/µL	10.94	109
Carbon Tetrachloride	10.00	ng/µL	11.15	112
1,2-Dichloroethane	10.00	ng/µL	11.30	113
Trichloroethene	10.00	ng/µL	8.90	89
1,1,2-Trichloroethane	10.00	ng/µL	12.17	122
Tetrachloroethene	10.00	ng/µL	9.30	93
1,1,1,2-Tetrachloroethane	10.00	ng/µL	11.69	117
1,1,2,2-tetrachloroethane	10.00	ng/µL	12.27	123

% Recovery – Percent recovery of analyte(s) from standard
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory
Analyses performed by: Richard Rodriguez

TABLE 9 CONTD.
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/10/97 Time: 7:37

COMPONENTS	INJECTED	UNITS	RECOVERED	% RECOVERY
Benzene	10.00	ng/µL	8.90	89
Toluene	10.00	ng/µL	8.60	86
Ethylbenzene	10.00	ng/µL	8.93	89
Total Xylenes	30.00	ng/µL	26.33	88
1,1- Dichloroethene	10.00	ng/µL	8.22	82
Vinyl Chloride	10.00	ng/µL	9.06	91
Methylene chloride	10.00	ng/µL	10.42	104
Trans-1,2-dichloroethene	10.00	ng/µL	8.62	86
1,1-Dichloroethane	10.00	ng/µL	11.17	112
Cis-1,2-Dichloroethene	10.00	ng/µL	8.87	89
Chloroform	10.00	ng/µL	13.34	133
1,1,1-Trichloroethane	10.00	ng/µL	10.94	109
Carbon Tetrachloride	10.00	ng/µL	11.15	112
1,2-Dichloroethane	10.00	ng/µL	11.30	113
Trichloroethene	10.00	ng/µL	8.90	89
1,1,2-Trichloroethane	10.00	ng/µL	12.17	122
Tetrachloroethene	10.00	ng/µL	9.30	93
1,1,1,2-Tetrachloroethane	10.00	ng/µL	11.69	117
1,1,2,2-tetrachloroethane	10.00	ng/µL	12.27	123

Date:9/10/97 Time: 12:39

COMPONENTS	INJECTED	UNITS	RECOVERED	% RECOVERY
Benzene	10.00	ng/µL	9.75	98
Toluene	10.00	ng/µL	9.71	97
Ethylbenzene	10.00	ng/µL	10.17	102
Total Xylenes	30.00	ng/µL	31.00	103
1,1- Dichloroethene	10.00	ng/µL	8.80	88
Vinyl Chloride	10.00	ng/µL	8.39	84
Methylene chloride	10.00	ng/µL	8.38	84
Trans-1,2-dichloroethene	10.00	ng/µL	9.07	91
1,1-Dichloroethane	10.00	ng/µL	8.40	84
Cis-1,2-Dichloroethene	10.00	ng/µL	9.69	97
Chloroform	10.00	ng/µL	9.45	95
1,1,1-Trichloroethane	10.00	ng/µL	9.33	93
Carbon Tetrachloride	10.00	ng/µL	10.22	102
1,2-Dichloroethane	10.00	ng/µL	9.64	96
Trichloroethene	10.00	ng/µL	9.81	98
1,1,2-Trichloroethane	10.00	ng/µL	11.31	113
Tetrachloroethene	10.00	ng/µL	9.67	97
1,1,1,2-Tetrachloroethane	10.00	ng/µL	10.84	108
1,1,2,2-tetrachloroethane	10.00	ng/µL	11.67	117

TABLE 9 CONTD.
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/10/97 Time: 18:30				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	9.97	100
Toluene	10.00	ng/µL	9.91	99
Ethylbenzene	10.00	ng/µL	9.99	100
Total Xylenes	30.00	ng/µL	29.46	98
1,1- Dichloroethene	10.00	ng/µL	9.67	97
Vinyl Chloride	10.00	ng/µL	9.57	96
Methylene chloride	10.00	ng/µL	9.51	95
Trans-1,2-dichloroethene	10.00	ng/µL	9.99	100
1,1-Dichloroethane	10.00	ng/µL	11.71	117
Cis-1,2-Dichloroethene	10.00	ng/µL	10.20	102
Chloroform	10.00	ng/µL	11.04	110
1,1,1-Trichloroethane	10.00	ng/µL	9.27	93
Carbon Tetrachloride	10.00	ng/µL	12.14	121
1,2-Dichloroethane	10.00	ng/µL	12.21	122
Trichloroethene	10.00	ng/µL	9.98	100
1,1,2-Trichloroethane	10.00	ng/µL	13.43	134
Tetrachloroethene	10.00	ng/µL	9.51	95
1,1,1,2-Tetrachloroethane	10.00	ng/µL	14.04	140
1,1,2,2-tetrachloroethane	10.00	ng/µL	14.87	149

% Recovery – Percent recovery of analyte(s) from standard
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory
Analyses performed by: Richard Rodriguez

TABLE 9 CONTD.
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/11/97 Time: 8:06				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	9.27	93
Toluene	10.00	ng/µL	9.31	93
Ethylbenzene	10.00	ng/µL	9.36	94
Total Xylenes	30.00	ng/µL	27.36	91
1,1- Dichloroethene	10.00	ng/µL	9.50	95
Vinyl Chloride	10.00	ng/µL	10.68	107
Methylene chloride	10.00	ng/µL	9.63	96
Trans-1,2-dichloroethene	10.00	ng/µL	9.58	96
1,1-Dichloroethane	10.00	ng/µL	10.31	103
Cis-1,2-Dichloroethene	10.00	ng/µL	9.50	95
Chloroform	10.00	ng/µL	11.69	117
1,1,1-Trichloroethane	10.00	ng/µL	9.94	99
Carbon Tetrachloride	10.00	ng/µL	10.05	101
1,2-Dichloroethane	10.00	ng/µL	8.68	87
Trichloroethene	10.00	ng/µL	9.41	94
1,1,2-Trichloroethane	10.00	ng/µL	11.39	114
Tetrachloroethene	10.00	ng/µL	8.99	90
1,1,1,2-Tetrachloroethane	10.00	ng/µL	10.26	103
1,1,2,2-tetrachloroethane	10.00	ng/µL	11.29	113

Date:9/11/97 Time: 13:38				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	9.21	92
Toluene	10.00	ng/µL	9.40	94
Ethylbenzene	10.00	ng/µL	8.48	85
Total Xylenes	30.00	ng/µL	29.69	99
1,1- Dichloroethene	10.00	ng/µL	7.00	70
Vinyl Chloride	10.00	ng/µL	9.80	98
Methylene chloride	10.00	ng/µL	10.68	107
Trans-1,2-dichloroethene	10.00	ng/µL	8.47	85
1,1-Dichloroethane	10.00	ng/µL	10.44	104
Cis-1,2-Dichloroethene	10.00	ng/µL	9.88	99
Chloroform	10.00	ng/µL	12.19	122
1,1,1-Trichloroethane	10.00	ng/µL	9.01	90
Carbon Tetrachloride	10.00	ng/µL	10.28	103
1,2-Dichloroethane	10.00	ng/µL	10.28	103
Trichloroethene	10.00	ng/µL	9.96	100
1,1,2-Trichloroethane	10.00	ng/µL	11.60	116
Tetrachloroethene	10.00	ng/µL	9.63	96
1,1,1,2-Tetrachloroethane	10.00	ng/µL	9.36	94
1,1,2,2-tetrachloroethane	10.00	ng/µL	11.03	110

TABLE 9 CONTD.
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/11/97 Time: 19:53				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	8.45	85
Toluene	10.00	ng/µL	8.69	87
Ethylbenzene	10.00	ng/µL	9.03	90
Total Xylenes	30.00	ng/µL	26.79	89
1,1- Dichloroethene	10.00	ng/µL	8.22	82
Vinyl Chloride	10.00	ng/µL	7.77	78
Methylene chloride	10.00	ng/µL	11.69	117
Trans-1,2-dichloroethene	10.00	ng/µL	8.22	82
1,1-Dichloroethane	10.00	ng/µL	10.35	104
Cis-1,2-Dichloroethene	10.00	ng/µL	8.48	85
Chloroform	10.00	ng/µL	11.44	114
1,1,1-Trichloroethane	10.00	ng/µL	8.85	89
Carbon Tetrachloride	10.00	ng/µL	10.00	100
1,2-Dichloroethane	10.00	ng/µL	10.35	104
Trichloroethene	10.00	ng/µL	8.70	87
1,1,2-Trichloroethane	10.00	ng/µL	11.08	111
Tetrachloroethene	10.00	ng/µL	8.73	87
1,1,1,2-Tetrachloroethane	10.00	ng/µL	11.38	114
1,1,2,2-tetrachloroethane	10.00	ng/µL	11.36	114

% Recovery – Percent recovery of analyte(s) from standard
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory
Analyses performed by: Richard Rodriguez

TABLE 9 CONTD.
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/12/97 Time: 10:01				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	10.01	100
Toluene	10.00	ng/µL	9.99	100
Ethylbenzene	10.00	ng/µL	9.97	100
Total Xylenes	30.00	ng/µL	30.04	100
1,1- Dichloroethene	10.00	ng/µL	10.00	100
Vinyl Chloride	10.00	ng/µL	9.99	100
Methylene chloride	10.00	ng/µL	7.68	77
Trans-1,2-dichloroethene	10.00	ng/µL	10.00	100
1,1-Dichloroethane	10.00	ng/µL	7.49	75
Cis-1,2-Dichloroethene	10.00	ng/µL	10.04	100
Chloroform	10.00	ng/µL	8.34	83
1,1,1-Trichloroethane	10.00	ng/µL	7.64	76
Carbon Tetrachloride	10.00	ng/µL	8.28	83
1,2-Dichloroethane	10.00	ng/µL	8.50	85
Trichloroethene	10.00	ng/µL	10.05	101
1,1,2-Trichloroethane	10.00	ng/µL	7.58	76
Tetrachloroethene	10.00	ng/µL	9.99	100
1,1,1,2-Tetrachloroethane	10.00	ng/µL	9.30	93
1,1,2,2-tetrachloroethane	10.00	ng/µL	8.68	87

Date:9/12/97 Time: 15:04				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	10.18	102
Toluene	10.00	ng/µL	10.00	100
Ethylbenzene	10.00	ng/µL	10.04	100
Total Xylenes	30.00	ng/µL	28.64	95
1,1- Dichloroethene	10.00	ng/µL	10.10	101
Vinyl Chloride	10.00	ng/µL	10.75	108
Methylene chloride	10.00	ng/µL	8.23	82
Trans-1,2-dichloroethene	10.00	ng/µL	10.31	103
1,1-Dichloroethane	10.00	ng/µL	9.07	91
Cis-1,2-Dichloroethene	10.00	ng/µL	10.27	103
Chloroform	10.00	ng/µL	9.67	97
1,1,1-Trichloroethane	10.00	ng/µL	8.82	88
Carbon Tetrachloride	10.00	ng/µL	9.97	100
1,2-Dichloroethane	10.00	ng/µL	10.65	107
Trichloroethene	10.00	ng/µL	10.01	100
1,1,2-Trichloroethane	10.00	ng/µL	11.84	118
Tetrachloroethene	10.00	ng/µL	9.95	100
1,1,1,2-Tetrachloroethane	10.00	ng/µL	11.59	116
1,1,2,2-tetrachloroethane	10.00	ng/µL	11.67	117

TABLE 9 CONTD.
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/17/97 Time: 7:24				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	10.98	110
Toluene	10.00	ng/µL	10.51	105
Ethylbenzene	10.00	ng/µL	10.49	105
Total Xylenes	30.00	ng/µL	31.30	104
1,1- Dichloroethene	10.00	ng/µL	11.41	114
Vinyl Chloride	10.00	ng/µL	9.63	96
Methylene chloride	10.00	ng/µL	8.39	84
Trans-1,2-dichloroethene	10.00	ng/µL	11.27	113
1,1-Dichloroethane	10.00	ng/µL	8.96	90
Cis-1,2-Dichloroethene	10.00	ng/µL	10.93	109
Chloroform	10.00	ng/µL	9.38	94
1,1,1-Trichloroethane	10.00	ng/µL	7.34	73
Carbon Tetrachloride	10.00	ng/µL	8.10	81
1,2-Dichloroethane	10.00	ng/µL	8.31	83
Trichloroethene	10.00	ng/µL	11.13	111
1,1,2-Trichloroethane	10.00	ng/µL	9.89	99
Tetrachloroethene	10.00	ng/µL	10.47	105
1,1,1,2-Tetrachloroethane	10.00	ng/µL	8.72	87
1,1,2,2-tetrachloroethane	10.00	ng/µL	8.20	82

Date:9/17/97 Time: 10:30				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	10.93	109
Toluene	10.00	ng/µL	11.02	110
Ethylbenzene	10.00	ng/µL	11.47	115
Total Xylenes	30.00	ng/µL	33.82	113
1,1- Dichloroethene	10.00	ng/µL	10.11	101
Vinyl Chloride	10.00	ng/µL	10.50	105
Methylene chloride	10.00	ng/µL	10.24	102
Trans-1,2-dichloroethene	10.00	ng/µL	10.90	109
1,1-Dichloroethane	10.00	ng/µL	11.31	113
Cis-1,2-Dichloroethene	10.00	ng/µL	10.88	109
Chloroform	10.00	ng/µL	10.00	100
1,1,1-Trichloroethane	10.00	ng/µL	8.52	85
Carbon Tetrachloride	10.00	ng/µL	9.27	93
1,2-Dichloroethane	10.00	ng/µL	9.62	96
Trichloroethene	10.00	ng/µL	10.89	109
1,1,2-Trichloroethane	10.00	ng/µL	11.31	113
Tetrachloroethene	10.00	ng/µL	11.49	115
1,1,1,2-Tetrachloroethane	10.00	ng/µL	10.46	105
1,1,2,2-tetrachloroethane	10.00	ng/µL	10.82	108

TABLE 9 CONTD.
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/17/97 Time: 16:32				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	10.91	109
Toluene	10.00	ng/µL	10.74	107
Ethylbenzene	10.00	ng/µL	10.76	108
Total Xylenes	30.00	ng/µL	32.34	108
1,1- Dichloroethene	10.00	ng/µL	10.37	104
Vinyl Chloride	10.00	ng/µL	10.95	110
Methylene chloride	10.00	ng/µL	10.29	103
Trans-1,2-dichloroethene	10.00	ng/µL	11.05	111
1,1-Dichloroethane	10.00	ng/µL	10.75	108
Cis-1,2-Dichloroethene	10.00	ng/µL	10.83	108
Chloroform	10.00	ng/µL	11.74	117
1,1,1-Trichloroethane	10.00	ng/µL	9.80	98
Carbon Tetrachloride	10.00	ng/µL	10.24	102
1,2-Dichloroethane	10.00	ng/µL	9.78	98
Trichloroethene	10.00	ng/µL	10.75	108
1,1,2-Trichloroethane	10.00	ng/µL	11.87	119
Tetrachloroethene	10.00	ng/µL	10.65	107
1,1,1,2-Tetrachloroethane	10.00	ng/µL	10.68	107
1,1,2,2-tetrachloroethane	10.00	ng/µL	11.66	117

% Recovery – Percent recovery of analyte(s) from standard
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory
Analyses performed by: Richard Rodriguez

TABLE 9 CONTD.
QA/QC Data Report for Soil Vapors (EPA methods 8010 and 8020)

Date:9/18/97 Time: 10:58				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	8.89	89
Toluene	10.00	ng/µL	8.70	87
Ethylbenzene	10.00	ng/µL	8.51	85
Total Xylenes	30.00	ng/µL	26.56	89
1,1- Dichloroethene	10.00	ng/µL	9.65	97
Vinyl Chloride	10.00	ng/µL	11.01	110
Methylene chloride	10.00	ng/µL	8.08	81
Trans-1,2-dichloroethene	10.00	ng/µL	9.40	94
1,1-Dichloroethane	10.00	ng/µL	8.64	86
Cis-1,2-Dichloroethene	10.00	ng/µL	9.12	91
Chloroform	10.00	ng/µL	9.71	97
1,1,1-Trichloroethane	10.00	ng/µL	8.25	83
Carbon Tetrachloride	10.00	ng/µL	8.66	87
1,2-Dichloroethane	10.00	ng/µL	8.72	87
Trichloroethene	10.00	ng/µL	9.03	90
1,1,2-Trichloroethane	10.00	ng/µL	9.08	91
Tetrachloroethene	10.00	ng/µL	8.41	84
1,1,1,2-Tetrachloroethane	10.00	ng/µL	9.39	94
1,1,2,2-tetrachloroethane	10.00	ng/µL	8.15	82

Date:9/18/97 Time:				
COMPONENTS	**INJECTED**	**UNITS**	**RECOVERED**	**% RECOVERY**
Benzene	10.00	ng/µL	8.57	86
Toluene	10.00	ng/µL	8.80	88
Ethylbenzene	10.00	ng/µL	10.51	105
Total Xylenes	30.00	ng/µL	28.16	94
1,1- Dichloroethene	10.00	ng/µL	8.15	82
Vinyl Chloride	10.00	ng/µL	8.37	84
Methylene chloride	10.00	ng/µL	10.29	103
Trans-1,2-dichloroethene	10.00	ng/µL	8.56	86
1,1-Dichloroethane	10.00	ng/µL	10.50	105
Cis-1,2-Dichloroethene	10.00	ng/µL	8.76	88
Chloroform	10.00	ng/µL	10.94	109
1,1,1-Trichloroethane	10.00	ng/µL	9.52	95
Carbon Tetrachloride	10.00	ng/µL	10.69	107
1,2-Dichloroethane	10.00	ng/µL	10.69	107
Trichloroethene	10.00	ng/µL	8.74	87
1,1,2-Trichloroethane	10.00	ng/µL	11.23	112
Tetrachloroethene	10.00	ng/µL	8.80	88
1,1,1,2-Tetrachloroethane	10.00	ng/µL	9.37	94
1,1,2,2-tetrachloroethane	10.00	ng/µL	10.74	107

% Recovery – Percent recovery of analyte(s) from standard
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory
Analyses performed by: Richard Rodriguez

TABLE 10
Matrix Spike (MS)/Matrix Spike Duplicate for Soils

ANALYSIS DATE: 9/16/97

COMPOUND	SPK CONC (mg/kg)	MS CONC (mg/kg)	MS %REC	MSD CONC (mg/kg)	MSD %REC	RPD %	ACCEPTABLE RPD	ACCEPTABLE %RECOVERY
Benzene	2	1.84	92%	1.77	89%	3.9%	15%	65%-135%
Toluene	2	1.91	96%	1.82	91%	4.8%	15%	65%-135%
Ethylbenzene	2	2.30	115%	2.31	116%	0.4%	15%	65%-135%
Total Xylenes	6	6.15	103%	5.59	93%	9.5%	15%	65%-135%
Vinyl Chloride	2	1.76	88%	1.97	99%	11.3%	15%	65%-135%
1,1- Dichloroethene	2	1.88	94%	1.77	89%	6.0%	15%	65%-135%
Trans-1,2-Dichloroethene	2	1.85	93%	1.72	86%	7.3%	15%	65%-135%
1,1-Dichloroethane	2	1.99	100%	1.93	97%	3.1%	15%	65%-135%
Cis-1,2-Dichloroethene	2	1.85	93%	1.81	91%	2.2%	15%	65%-135%
Chloroform	2	2.34	117%	2.11	106%	10.3%	15%	65%-135%
1,1,1-Trichloroethane	2	1.95	98%	1.80	90%	8.0%	15%	65%-135%
Carbon Tetrachloride	2	1.77	89%	1.92	96%	8.1%	15%	65%-135%
1,2-Dichloroethane	2	1.65	83%	1.99	100%	18.7%	15%	65%-135%
Trichloroethene	2	1.85	93%	1.94	97%	4.7%	15%	65%-135%
1,1,2-Trichloroethane	2	2.08	104%	2.11	106%	1.4%	15%	65%-135%
Tetrachloroethene	2	1.78	89%	1.81	91%	1.7%	15%	65%-135%
1,1,1,2-Tetrachloroethane	2	1.91	96%	2.02	101%	5.6%	15%	65%-135%
1,1,2,2-Tetrachloroethane	2	2.08	104%	2.17	109%	4.2%	15%	65%-135%

SPK CONC – Concentration spiked into matrix.
MS CONC – Analyzed concentration of spiked sample.
% REC – Percent recovery of spike from matrix.
RPD – Relative percent difference between matrix spike and matrix spike duplicate
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses Performed by: Richard Rodriguez

TABLE 10 CONTD.
Matrix Spike (MS)/Matrix Spike Duplicate for Soils

ANALYSIS DATE : 9/17/97

COMPOUND	SPK CONC (mg/kg)	MS CONC (mg/kg)	MS %REC	MSD CONC (mg/kg)	MSD %REC	RPD %	ACCEPTABLE RPD	ACCEPTABLE %RECOVERY
Benzene	2	1.74	87%	1.69	85%	2.9%	15%	65%-135%
Toluene	2	1.73	87%	1.72	86%	0.6%	15%	65%-135%
Ethylbenzene	2	1.67	84%	1.75	88%	4.7%	15%	65%-135%
Total Xylenes	6	5.35	89%	4.99	83%	7.0%	15%	65%-135%
Vinyl Chloride	2	1.87	94%	1.80	90%	3.8%	15%	65%-135%
1,1- Dichloroethene	2	1.72	86%	1.70	85%	1.2%	15%	65%-135%
Trans-1,2-Dichloroethene	2	1.75	88%	1.75	88%	0.0%	15%	65%-135%
1,1-Dichloroethane	2	1.89	95%	1.83	92%	3.2%	15%	65%-135%
Cis-1,2-Dichloroethene	2	1.74	87%	1.73	87%	0.6%	15%	65%-135%
Chloroform	2	2.08	104%	2.21	111%	6.1%	15%	65%-135%
1,1,1-Trichloroethane	2	1.67	84%	1.84	92%	9.7%	15%	65%-135%
Carbon Tetrachloride	2	1.86	93%	1.74	87%	6.7%	15%	65%-135%
1,2-Dichloroethane	2	1.74	87%	1.78	89%	2.3%	15%	65%-135%
Trichloroethene	2	1.76	88%	1.78	89%	1.1%	15%	65%-135%
1,1,2-Trichloroethane	2	2.08	104%	2.19	110%	5.2%	15%	65%-135%
Tetrachloroethene	2	1.75	88%	1.59	80%	9.6%	15%	65%-135%
1,1,1,2-Tetrachloroethane	2	2.01	101%	1.96	98%	2.5%	15%	65%-135%
1,1,2,2-Tetrachloroethane	2	2.12	106%	1.96	98%	7.8%	15%	65%-135%

SPK CONC – Concentration spiked into matrix.
MS CONC – Analyzed concentration of spiked sample.
% REC – Percent recovery of spike from matrix.
RPD – Relative percent difference between matrix spike and matrix spike duplicate
Analyses performed on site in TEG-Texas Mobile Environmental Laboratory.
Analyses Performed by: Richard Rodriguez

ATTACHMENT A

Soil Boring Logs

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET	OF
111494.51.03	1414-S1	1	1

9/16/97

SOIL BORING LOG

PROJECT Zone 5 Sewer Investigation LOCATION bldg 1414

ELEVATION _____ DRILLING CONTRACTOR TEG

DRILLING METHOD AND EQUIPMENT Strataprobe 2"x2' Split Spoon w/Acetate liners

WATER LEVELS _____ START 9/16/97 0845 FINISH 1010 LOGGER M. Wilson

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
					Asphalt + road base use Solid point No Recovery	
	2-4	SS-1	2.0'	—	clay (CL), Dark gray, moist, soft.	1.6 ppm (Sample Collected @ 0855) 3'-4'
5	4-6	SS-2	2.0	—	As above	11 ppm (Sample Collected 0900) 5'-6'
	6-8	SS-3		—	Sample stuck in barrel, wait to extrude clay (CL) As above	10 ppm (Sample Collected 1130) 7'-8'
	8-10	SS-4	2.0	—	0-0.1 - blk clay as above 0.1-2.0 - Clay (CL) brn/gray, Stiff, Some Caliche present	1.6 ppm ø ppm
10	10-12	SS-5	2.0	—	As above Clay, increase in Caliche	ø ppm
	12-14	SS-6	2.0	—	As above increase in Silt	ø ppm
15	14-16	SS-7	1.5	—	clay (CL) brn, V. lean, Dry, crumbly, Trace of sand, little to no Caliche	ø ppm
	16-18	SS-8	1.0	—	As above, V. hard to hammer	ø ppm
	-	SS-9	0.1		As above	ø ppm
				TD-18.5 refusal		

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET	OF
111494.51.03	1414-52	1	1
9/16/97	SOIL BORING LOG		

PROJECT Zone 5 Sewer Investigation LOCATION bldg 1414

ELEVATION _____ DRILLING CONTRACTOR TEG

DRILLING METHOD AND EQUIPMENT Strataprobe 2"x2' SS w/ Acetate liners

WATER LEVELS _____ START 9/16/97 1115 FINISH 1200 LOGGER M. Wilson

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	—	—	—	—	Asphalt 6" - 6" Fill material (x soil probe no recovery)	
	1-2	SS-1	1.0'	—	Clay (CL) dk brn/gray fill material some Sand	Øppm
	2-4	SS-2	2.0	—	Clay (CL) - as above	Øppm 1125 Sample 3'-4'
5	4-6	SS-3	0.5	-	As above increase in Moisture Clay (CL)	Øppm Acetate liner Crushed
	6-8	SS-4	1.0	—	As Above Clay (CL)	Øppm
	8-10	SS-5	1.5	—	0-6" (As above) 6"-15" Clay (CL) red/brn, dry, brittle Abundant gravel & Caliche	Øppm
10	10-12	SS-6	1.0	—	Clay (CL) red/brn, dry, Stiff Abundant Caliche	Øppm
	12-14	SS-7	1.0	—	As above, V. Stiff	Øppm
15					TD-14' refusal	

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CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET	OF
111494.51.03	1414-53	1	1

9/16/97

SOIL BORING LOG

PROJECT Zone 5 Sewer Investigation LOCATION Bldg 1414

ELEVATION _____ DRILLING CONTRACTOR TEG

DRILLING METHOD AND EQUIPMENT Strataprobe 2"x2' SS w/ Acetate liners

WATER LEVELS _____ START 9/16/97 1315 FINISH 1400 LOGGER M. Wilson

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	0-1				Asphalt, road base Solid point	
	1-2	SS-1	1.0	—	Clay (cl) dk gray - black, moist, soft trace	3ppm
	2-4	SS-2	1.0	—	clay As above	2ppm
5	4-6	SS-3	1.5	—	Clay as above	3ppm Sample 1335 1414-53
	6-8	SS-4	—	—	No recovery	
	8-10	SS-5	1.5	—	0.5- As above 0.5-1.5- Clay (cl) reddish brn, Dry, V. Stiff abundant Caliche gravel	3ppm Sample 1345
	10-12	SS-6	2.0	—	Clay red As above	0ppm
	12-13	SS-7	0.8	—	As above w/ increase in Caliche	0ppm
					13-TD refusal	

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET	OF
111494.51.03	1414-S4	1	1
9/16/97	SOIL BORING LOG		

PROJECT Zone 5 Sewer Investigation LOCATION Bldg 1414

ELEVATION _____ DRILLING CONTRACTOR IEG

DRILLING METHOD AND EQUIPMENT Strataprobe 2"X2' SS w/ Acetate liners

WATER LEVELS _____ START 1445 FINISH 1615 LOGGER M. Wilson

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	0-2	SS-1	1.0	—	0-1' Asphalt/Road Base Solid Point 1'-2'- Clay (cl) BR, moist soft.	0.7 Sample
	2-4	SS-2	1.0	—	Clay As above	Øppm
	4-6	SS-3	1.0	—	Clay As above	Øppm
	6-8	SS-4	2.0	—	0-0.2 - As above 0.2-2.0 - Clay (cl) brn/orng, dry, stiff Abundant gravel & Caliche	0.2ppm
	8-10	SS-5	1.0	—	As above Clay reddish brn Increase in Moisture.	Øppm
	10-12	SS-6	2.0	—	Silty Clay (cl) brn, sl. moist stiff, Crumbly, Some gravel & Caliche	0.7ppm
	12-14	SS-7	1.5	—	Clay As above	1ppm
	14-16	SS-8	2.0	—	Silty Clay (cl) light brn, v. moist, firm, crumbly, little Sand	2.5ppm Sample
	16-18	SS-9	1.0	—	As above	Øppm
	18-20	SS-10	2.0	—	As above	1.0ppm
	20-21	SS-11	0.6	—	As above Abundant Caliche	Øppm
					TD-21' Refusal	

REV 9/96 FORM D1586

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET	OF
111494.51.03	1414-SS	1	1

9/17/97

SOIL BORING LOG

PROJECT Zone 5 Sewer Investigation LOCATION bldg 1414

ELEVATION _____ DRILLING CONTRACTOR TEG

DRILLING METHOD AND EQUIPMENT Stratoprobe 2"X2' SS w/ Acetate liners

WATER LEVELS _____ START 9/17/97 0835 FINISH 0935 LOGGER M.Wilson

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	0-2	SS-1	1.5	—	Clay ( ) black to dark gray, V. dry, V. stiff, organics present, some gravel (fill mat.)	0 ppm
	2-4	SS-2	2.0	—	Clay w/ gravel ( ) black to dark gray, dry, gravel upto 4cm, (fill mat.)	0 ppm
5	4-6	SS-3	2.0	—	Clay (CL) dark brn, dry, stiff, little Sand & gravel	0 ppm Sample 0845
	6-8	SS-4	2.0	—	0-1' As above 1-2' gravelly clay ( ) reddish brn, abundant chert & caliche, sl. moist	0 ppm
	8-10	SS-5	2.0	—	As above.	4.0 ppm Sample 0900
10	10-12	SS-6	2.0	—	As above 0-1.5' 1.5'-2.0' clay (CL) reddish brn, sl. moist, crumbly (lean),	0.5 ppm
	12-14	SS-7	2.0	—	Silty Clay (CL) reddish brn, sl. moist Trace of Sands	0 ppm
15	14-16	SS-8	2.0	—	As above Some Caliche @ 15'	0 ppm
	16-18	SS-9	2.0	—	0-1.5' - As above. 1.5'-2.0' - Silty clay w/ abundant caliche & chert, moist,	0 ppm
					refus. 1 @ 18', TD	

REV 9/96 FORM D1586

CH2MHILL

18E

PROJECT NUMBER	BORING NUMBER	SHEET	OF
111494.51.03	2000-S1		1

9/17/97

SOIL BORING LOG

PROJECT Zone 5 Sewer Investigation LOCATION Flightline

ELEVATION _____ DRILLING CONTRACTOR TEG

DRILLING METHOD AND EQUIPMENT Stratoprobe 2"X2' SS w/ Acetate liners

WATER LEVELS _____ START 9/17/97 1055 FINISH 1135 LOGGER M. Wilson

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	0-2	SS-1	2'	—	Gravelly Clay ( ) Dk brn, dry, loose, abundant Sand + gravel to 1 cm	0 ppm
	2-4	SS-2	1.5	-	Clay (CH), Dry, Stiff, V. little Sand (f-c) organic	0 ppm
5	4-6	SS-3	2.0	-	0-.5' - As above .5-2.0 - Med Gravelly clay ( ) med brn, dry loose,	0 ppm
	6-8	SS-4	2.0'	—	0-1.5' (As above) 1.5-2.0 - Silt ( ) reddish brn, dry, crumbly Contains some weathered Caliche	0 ppm 0.4 ppm Sample 1115
	8-10	SS-5	2.0	—	As Above w/ pockets of Clay	0 ppm
10	10-12	SS-6	2.0	—	0-1.0 - As above 1.0-2.0 - Weathered + unweathered Caliche Caliche, dry, V. hard	0 ppm
				refusal 12' TD		

(8.30)

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Appendix C

Off Base Study/Mitretek Report

The findings of the Mitretek Report have been summarized in Section 9.0.

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Appendix D

Seismic Reflection Profiling/ Top of Navarro Group Contour Map

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Seismic Reflection Profiling/Top of Navarro Group Contour Map

1.0 Investigation Method

The seismic reflection survey, a supplemental investigation for Zone 5, was conducted by ***Interpre' Tech/SeisPulse LLC*** in August of 1996. The primary purpose of the investigation was to estimate the depth of Navarro group and to prepare the top of Navarro contour map for Zone 5. The seismic reflection investigation is summarized in the following sections. The resulting information was combined with other data sources to prepare a contour map of the top of the Navarro Group.

The ***SeisPulse*** seismic source (U.S. Pat. 5,416,282) and the "near offset" method of seismic survey (U.S. Pat. 5,416,282) were selected by ***Interpre' Tech/SeisPulse LLC*** to accomplish the investigation. The ***SeisPulse*** seismic source applied in Zone 5 investigations consisted of a mixture of propane gas and air. The source energy was initiated by explosion of gases contained within a firing chamber. This explosion created a shock wave that was directed down a wave guide, which was specifically designed for the maximum transmission of energy where it impacted the ground surface, creating a seismic wave. The elastic nature of the shock wave also inhibited the outward propagation of near-surface ground waves that sometimes interfere with incoming reflection data.

The "near offset" method utilized one channel to record the reflection data and a separate channel for the sum of the individual channels while maintaining a constant offset between source and receiver. The constant offset between the source and receiver was one foot. That minimized interference between the reflected data and the ground roll and air wave by allowing the destructive interference to pass after the arrival of the data of interest. The one foot offset method also made it possible to use the positive aspects of both the common mid-point seismic reflection technique and the optimum offset method of seismic data acquisition.

2.0 Field Procedure

The fieldwork was conducted in two phases: velocity check shot survey and field production. The purpose of the velocity check shot survey was to determine the velocities necessary for time-depth conversion. The velocity check shot surveys performed for Zone 5 involved lowering a geophone (receiver) down a well borehole to a known depth, and measuring the traveltime of the seismic wave generated by a signal source located on the ground surface adjacent to the well. The geophone was lowered sequentially through a number of depth intervals (3 to 5 ft), and the traveltimes were measured at each depth. The difference of traveltimes between a number of geophone depths was used to derive the seismic velocity within the depth interval of the geophone locations. Velocity check shot surveys were

completed at eighteen shallow borings in Zone 5. The locations of the 18 borings (wells) are shown in Figure D.1.

The field production included the acquisition of 23 seismic reflection lines in the selected areas. Each seismic line consists of a series of shotpoints acquired at a predetermined interval (10 ft). The locations of the 23 lines and the shotpoints are shown in Figure D.1. Data acquisition began at shotpoint 1 with the layout of a single geophone kept a constant offset of 1 ft from the source. The geophone was connected directly to a roll-a-long switching unit, which in turn was connected to a 12 channel seismic recording unit. With the firing of the source, vertical reflection data was recorded directly on to Channel 1 and Channel 12. When the next shot was initiated, reflection data was recorded on Channel 2 and summed on Channel 12. This sequence continued until the required number of shots for that station were completed. With the completion of data acquisition for that specific station, the data was saved to an individual data file, the source and geophone were picked up, and the system was moved to the next station. This process was repeated along the length of the seismic line. Some of the seismic lines were separated into sub-units for the ease of data processing and general data handling.

3.0 Data Acquisition and Reflection Profiles

Data for this investigation was acquired using two active channels of a 12-channel Geometrics S-12 seismograph and two Mark Products geophone. All data was recorded at a ¼ msec sample interval and a record length of 512 msec. Data acquisition was accomplished using the ***SeisPulse*** "near offset" method of seismic reflection survey.

Data was acquired on 10 ft shot point spacing. The signal to noise ratio of the final record at each shot point was increased by summing individual records acquired at each shot point. This rationale assumes that all real reflectors will arrive at the same time and thus be additive, while noise is random and will not be additive. A minimum of nine sums were used for each shot point throughout the survey.

The reflection profiles were generated by plotting cross-sections on each of the seismic sections. The cross-sections were prepared by integrating the elevation data obtained from Zone 5 topographic map. Navarro Group depths determined from the soil borings were converted and then plotted to time on each of the seismic sections. The reflection profiles, prepared and provided by ***Interpre' Tech/SeisPulse LLC***, are available in CH2M HILL project files.

4.0 Quality Control/Quality Assurance

The method of controlling the quality of shallow seismic data acquisition should have the ability to assure that the data acquired is in fact, a reflection and not another source of wave energy. One of the most common methods is to conduct a walk-away noise test. The one-foot walk-away method was used for the Zone 5 investigation. This method was conducted by providing a stationary source and moving the geophone (receiver) at one foot incremental distances away from the source. This enables the identification the direct surface wave (groundroll) which is moving at a constant velocity and appears sloped, while the reflector

should appear coherent and flat. The time necessary to complete an individual QA/QC noise test is approximately 30 minutes.

4.0 Data Processing

The seismic data processing was done on a microcomputer using *EavesDroppe*r, a set of commercial data processing algorithms available from Kansas Geological Survey (KGS). The initial data processing flow was similar to those used to process seismic data in oil and gas exploration with the exception of the algorithms necessary to provide time variant filtering and spectral whiting. The following procedure was used for the data processing flow:

1. Conversion from Geometrics to KGS *EavesDroppe* format
2. Edit traces
3. Sort data
4. Scale (500 msec window)
5. Filter-bp (HZ) 80-100-135-270
6. Scale (120 msec window)
7. Residual statics (10 msec window, 3 msec max shift)
8. Mute
9. Stack.

Initial data processing was completed using a narrow band pass filter whose frequencies were 30-40-50-60 (HZ). Low frequency cultural noise (pumps, etc.) was observed to interfere and distort the Navarro reflector. Therefore, a higher frequency band pass filter was employed for the final and interpreted seismic sections.

5.0 Results

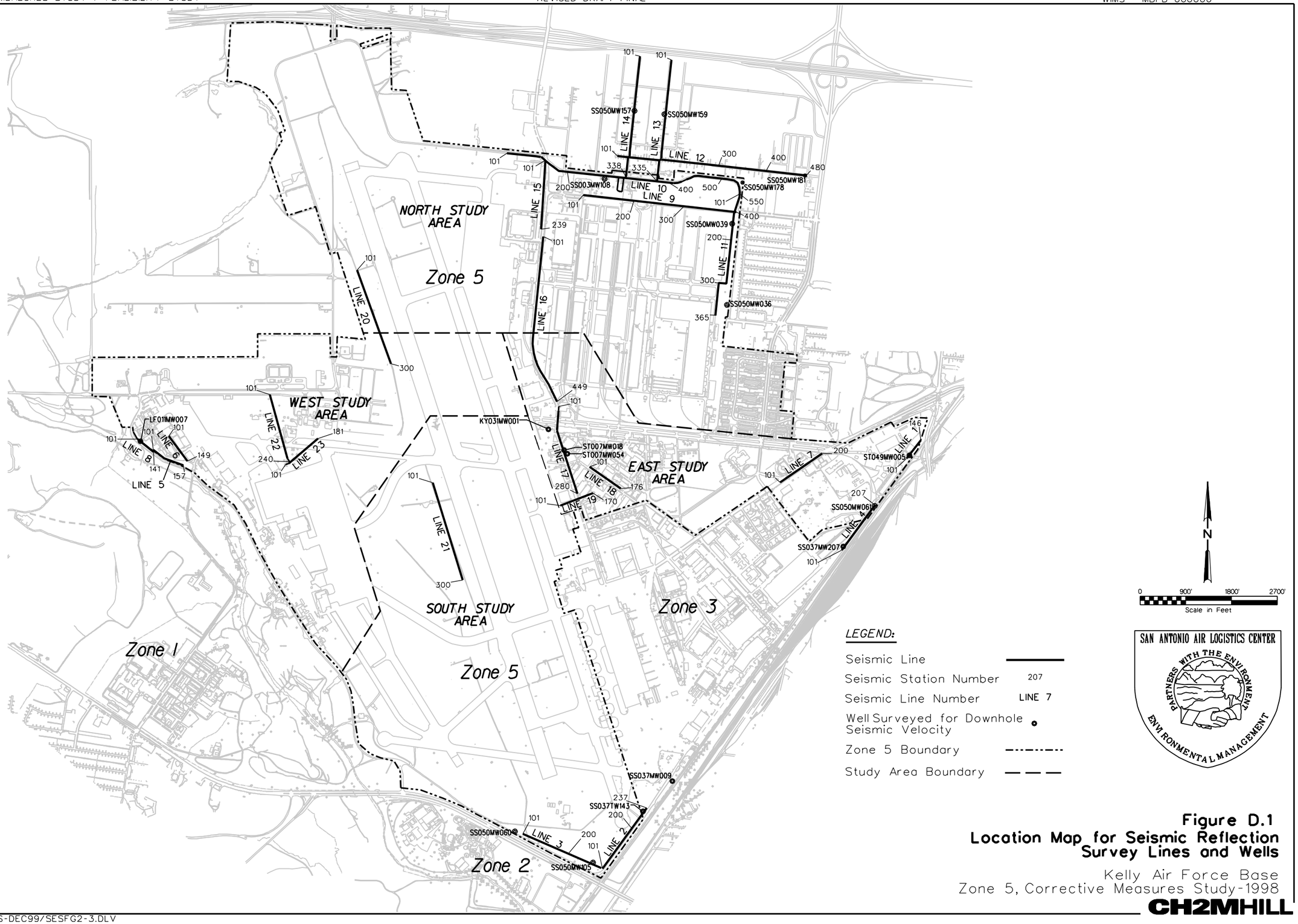
While the interval velocities obtained from check shot data varied throughout the site, average velocities to the top of the Navarro remained reasonably constant (1,575 ft/sec) from borehole to borehole through out Zone 5, with the exception of the Eastern Study Area. From both the current and previous geophysical investigations of this area, the average velocity to the top of the Navarro was observed to increase from 1,575 ft/sec to 2,000 ft/sec. Therefore, an average velocity of 2,000 ft/sec was used to compute the depth to the top of the Navarro Group on Lines 1, 4, and 7 (Figure D.1).

The reflection survey data was time-tied at all line intersection in the survey. All data was converted to the Navarro depths using the average velocity of 1,575 ft/sec or 2,000 ft/sec. The calculated depths were then compared with the actual Navarro depths in the areas where seismic lines cross or close enough to the soil borings. Seismic depth deviations from actual were an indicator of the seismic survey accuracy at localized areas. With few exceptions, seismic

derived depths were within 10% or less of borehole depths. The deviations varied from 0 to ±5 ft due to the use of a constant velocity throughout the survey area.

The top of Navarro map, Figure D.2, was generated based on the seismic reflection data and the soil boring data collected from the other studies. The method used to develop the Navarro surface map has been described in a report by CH2M HILL (1998)[1].

[1] CH2M HILL. "1997 Groundwater Recovery System Performance Modeling and Navarro/Midway Group Surface and Gravel Thickness Mapping." Draft report submitted to Kelly AFB, Texas, Contract No. is F41650-95-2005-5024, CH2M HILL Project Number 139315. April 1998.



LEGEND:

- Seismic Line
- Seismic Station Number 207
- Seismic Line Number LINE 7
- Well Surveyed for Downhole Seismic Velocity
- Zone 5 Boundary
- Study Area Boundary

SAN ANTONIO AIR LOGISTICS CENTER
PARTNERS WITH THE ENVIRONMENT
ENVIRONMENTAL MANAGEMENT

Figure D.1
Location Map for Seismic Reflection Survey Lines and Wells

Kelly Air Force Base
Zone 5, Corrective Measures Study-1998

CH2MHILL

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Appendix E

Zone 5 RI Supplemental Characterization Data

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Zone 5 Supplemental Characterization

1.0 Soil Borings and Monitoring Well Locations

Between November 11 and December 8, 1998, a total of 15 additional soil borings and 18 additional monitoring wells were drilled to conduct the supplemental investigation for the Zone 5 Remedial Investigation/Feasibility Study (RI/FS). The wells and borings provided additional soil and groundwater data for four separate sites in Zone 5.

The purpose and location of the wells and borings were as follows:

- Twelve of the wells further defined the extent of the off-base contaminant plume north of Kelly Air Force Base (AFB).
- Four wells and 12 borings were used to further evaluate a potential source area in the vicinity of Building 1414 and to define the limits of contamination associated with a solid waste management unit (SWMU) at Building 1418, the oil water separator (OWS).
- At IRP Site S-10, two wells and three soil borings were installed to further define the contaminant plume and source area. The borings provided additional data to evaluate potential source(s) of contamination to the underlying groundwater. The off-base monitoring wells further defined the extent of existing groundwater contamination.

Figures E-1, E-2, and E-3 show the locations of the new soil borings and monitoring wells.

1.1 Building 1414

Figure E-1 shows the soil boring and monitoring well locations around Building 1414. Locations were selected on the following basis:

- **SS025SB017** Located in an area where 1960 photos indicated a parked aircraft that appeared to be having maintenance performed on it.
- **SS025SB018** Located in an area with stressed vegetation that received run-off from the concrete slab.
- **SS025SB019** Located in an area that could potentially have been the site of the solvent drum storage area (based on the aerial photographs).
- **SS025SB020** Located along the sanitary sewer line where soil vapor samples detected trichloroethene (TCE). Deep soil samples (from near the water table) were not collected previously, in part due to refusal of the Strataprobe® direct push drill rig.
- **SS025SB021** Located along the sanitary sewer line where soil vapor samples detected TCE. Deep soil samples (from near the water table) were not collected previously, in part due to refusal of the Strataprobe® direct push drill rig.
- **SS025SB022** Located along the sanitary sewer line where soil vapor samples detected TCE. Deep soil samples (from near the water table) were not collected previously, in part due to refusal of the Strataprobe® direct push drill rig.

- **SS025SB023** Located along the sanitary sewer line where soil vapor samples (both Zone 5 and the sewer investigation) detected TCE. Deep soil samples (from near the water table) from a nearby well detected organic compounds. Groundwater from this nearby well had detections of solvents.
- **SS025SB024** Located along a sewer line extending from a former wash rack located at the northeast corner of Building 1414 to the OWS at Building 1480.
- **SS025SB025** Located along a sewer line extending from a former wash rack located at the northeast corner of Building 1414 to the OWS at Building 1480.
- **SS025SB026** Located along the concrete slab stormwater drainage system piping. The location is upgradient of the area excavated during removal of an OWS. The limit of the excavated area still had detected concentrations of solvents.
- **SS025SB027** Located at the former OWS.
- **SS025SB028** Located along a sewer line extending from a former wash rack located at the northeast corner of Building 1414 to the OWS at Building 1480.
- **SS050MW468** Located on the upgradient side of the concrete slab. The monitoring well is located in an area with stressed vegetation that received run-off from the concrete slab.
- **SS050MW469** Located downgradient of the OWS. Deep soil samples (from near the water table) were not collected previously, in part due to refusal of the Strataprobe® direct push drill rig.
- **SS050MW470** Located downgradient of the OWS. Nearby (SOV) data had detections of solvents in soil and groundwater.
- **SS050MW471** Located adjacent to the manhole of the sewer line from the above-mentioned wash rack to the OWS to assess possible groundwater contamination between SS025MW006 and SS050MW044.

1.2 IRP Site S-10

Figure E-2 shows the soil boring and monitoring well locations around IRP Site S-10. Locations were selected on the following basis:

- **SS045SB017** Located adjacent to monitoring well ST007MW053 to investigate possible sources for tetrachloroethene (PCE) groundwater contamination.
- **SS045SB018** Located adjacent to the concrete slab where aircraft maintenance was performed to investigate possible sources for PCE groundwater contamination.
- **SS045SB019** Located adjacent to the concrete slab where aircraft maintenance was performed to investigate possible sources for PCE groundwater contamination.
- **SS050MW472** Located between Site S-10, PCE-contaminated groundwater, and TCE-contaminated groundwater to the southeast to determine the extent of PCE in the groundwater at Site S-10.

- **SS050MW473** Located between Site S-10, PCE-contaminated groundwater, and TCE-contaminated groundwater to the southeast to determine the extent of PCE in the groundwater at Site S-10.

1.3 Off-Base Plume Delineation

Figure E-3 shows the off-base monitoring well locations. Locations were selected as follows:

- **SS050MW334** through **SS050MW341** Located off-base east and northeast of Zone 5 to define the extent of the off-base TCE plume.
- **SS050MW342** through **SS050MW345** Located off-base north and northeast of Zone 5 to define the extent of the off-base PCE plume

The 12 off-base monitoring wells north and east of Main Kelly, were drilled and installed within City of San Antonio right-of-way. The sequence of well installation was based on sampling results from the initial wells. The wells closest to the base boundary were installed first. Volatile organic compounds (VOCs) were analyzed in the lab within 48 hours. The analytical results from these samples were used to determine whether or not the next series of off-base wells would be drilled. The results of the VOC sampling dictated that all of the proposed off-base wells were drilled and sampled.

2.0 Soil Boring and Monitoring Well Installation

Each soil boring was drilled to the bottom of the shallow aquifer (depths ranged from 24 to 36 feet) using a 4.25-inch-inside-diameter (ID) hollow-stem auger. Soils were sampled continuously during drilling with 2-feet-long by 2- or 3-inch-diameter split spoon sampler depending on the difficulty of penetrating the subsurface clays and gravels. The continuous samples were used to log the soil boring, and each split-spoon sample was surveyed with an Organic Vapor Meter (OVM) and recorded on the boring log. From the continuous soil samples, two intervals of the soil cores were selected for analytical testing. The specific sample intervals were pre-selected based on previous information prior to installing the soil boring and/or were selected from the zone(s) with the highest organic vapor monitoring (OVM) readings. A total of 30 soil samples were collected from the soil borings.

Upon completion, each boring was grouted to ground surface with a cement/bentonite grout using the tremie method. All soil cuttings produced during drilling were containerized and transported by the drilling contractor to the designated staging area in Zone 2. Additional information regarding the handling and disposal of soil cuttings, as well as decontamination fluids and personal protection equipment, can be found in the *Waste Management Plan*.

All monitoring wells were drilled with 4.25-inch-ID hollow-stem augers and were sampled continuously with 2-foot-long by 2- or 3-inch-diameter split-spoon samplers. Twelve soil samples for laboratory analysis were collected, two from each of the six on-base monitoring well borings. The sample intervals were either pre-selected based on previous information prior to installing the soil boring, or were selected from the zone(s) with the highest OVM readings. No soil samples were collected from the off-base monitoring well borings, because the off-base monitoring wells were installed for groundwater monitoring only.

All drill cuttings were staged in Department of Transportation-approved containers. The onsite CH2M HILL hydrogeologist chose the total boring depths and screened intervals. Wells and soil borings were installed at a depth equal to the top of the Navarro clay.

2.1 Drilling Methods

Drilling operations were conducted in a manner that would accomplish the following:

- Prevent the spread of contamination
- Minimize the disruption of existing conditions
- Minimize long-term effects
- Minimize the introduction of foreign materials into the borehole
- Ensure worker safety
- Conform to all applicable federal, state, and local regulations

A licensed surveyor surveyed the locations of monitoring wells and tied them to the existing Kelly AFB grid system. Horizontal locations were surveyed to the nearest 0.01 foot using the Texas State Plane Coordinate System. Elevations of monitoring wells were surveyed to the nearest 0.01 foot.

The CH2M HILL hydrogeologist supervised and maintained the records of drilling and monitoring well installations. The hydrogeologist logged each soil and monitoring well boring, and filled out well completion forms. (see Attachment A). Geologic descriptions used standard lithology terminology and symbols, according to the Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), ASTM D 2488.

2.2 Soil Sampling

Two soil samples were collected from each soil boring and from the on-base monitoring well borings. Samples were collected from the depth intervals most likely to contain contamination (i.e., below the sewer lines) and/or at any interval that appeared to be contaminated based on visual inspection and/or organic vapor monitoring (OVM) of the sample cores. If no contamination was visible or suspected, samples were collected at a minimum from the surface interval (zero to 2 feet) and from the vadose zone. All soil samples from the soil borings were analyzed for VOCs, semi-volatile organic compounds (SVOCs), and metals. Soil samples from the six on-base monitoring well borings were analyzed for VOCs and metals only.

2.3 Well Installation

Two-inch monitoring wells were installed through the hollow-stem augers. Wells were constructed with 10 feet of 0.01-inch, wire-wrapped stainless steel screen, stainless steel riser below the water table and schedule 40 polyvinyl chloride (PVC) riser above the water table. A silica sand pack with a gradation of 20 to 40 was installed to 2 feet above the top of the screen. A 2-foot-thick bentonite pellet seal was placed on top of the sand pack. The bentonite pellets were hydrated with de-ionized water. After the bentonite pellets hydrated sufficiently, the open borehole annulus was grouted to approximately 3 feet bgs with neat cement/bentonite grout.

Because of the rapid schedule required for obtaining rapid analytical results for the VOC samples, the off-base wells were developed and sampled prior to installation of the neat cement/bentonite grout. The on-base wells were developed and sampled a minimum of 24 hours after well installation.

Each monitoring well was developed by pumping. Specific conductivity, pH, and temperature of the development water were measured periodically. Development continued until these parameters were stable and the well produced water acceptably free of sediment. All development water was contained and discharged to the Environmental Process Control Facility (EPCF) under the direction of Kelly AFB.

All monitoring wells were completed with expandable locking caps, 8-inch-diameter manhole covers, and 4.5-feet by 4.5-feet concrete pads. Pads were constructed of concrete reinforced with rebar. A brass well identification plate was placed in each pad.

2.4 Groundwater Sampling

Groundwater samples were collected from the 18 newly installed monitoring wells. Each of the six on-base wells was purged of at least three well volumes of water by pumping before sampling. The pre-sample pumping was conducted at a slow rate to minimize the production of suspended solids in the samples. Specific conductivity, pH, and temperature of the purge water were measured periodically, and purging continued until these parameters were sufficiently stable.

The groundwater samples collected from the 12 off-base wells, which required 48-hour turnaround for VOC analyses, were collected immediately following well development activities. These wells were developed and sampled within 24 hours of installing the bentonite seal, but before grouting. Groundwater parameters collected during well development were used to ensure that the samples represented aquifer conditions.

All groundwater samples were analyzed for VOCs, SVOCs, and metals.

Groundwater samples were stored on ice and shipped daily to the analytical laboratory by overnight freight. Chain-of-custody records were maintained for all samples.

3.0 Results of Supplemental Characterization Sampling

3.1 Building 1414

Twelve soil borings (SS025SB017 to SS025SB028) and four monitoring wells (SS050MW468 to SS050MW471) were installed in the vicinity of Building 1414 between November 11 and December 7, 1998. The total depths ranged from 27.5 feet to 36 feet below ground surface (bgs) with an average depth of 31 feet. Two soil samples were collected from each soil and monitoring well boring (as described in Section 2.2). Soil samples from the soil borings were analyzed for VOCs, SVOCs, and metals. Soil samples from monitoring well borings were analyzed for VOCs and metals only. Data summary tables in Attachment B summarize sample stations, depths, and results.

3.1.1 Results of Soil Sampling

Figure E-4 shows VOC and SVOC soil detections in the vicinity of Building 1414. TCE was detected at only 2 of the 12 soil boring locations: SS025SB021 and SS025SB022. DCE was detected at three soil borings locations: SS025SB018, SS025SB020, and SS025SB022. Chlorobenzene was detected at one soil boring: SS025SB025. Naphthalene and 2-methylnaphthalene were detected at SS025SB027 adjacent to the OWS SWMU at Building 1418. All constituents detected in the soil in the vicinity of Building 1414 were below the TNRCC groundwater protection standards for soils. The isolated nature of the various contaminants in the soils did not suggest a clear definition of a source area for contaminants associated with Buildings 1414, 1416, or 1418.

A total of nine soil samples had detections of cadmium that slightly exceeded background values. The maximum value detected was 0.76 milligrams per kilogram (mg/kg). These detections are considered of urban environmental or mineralogical origin and are not considered representative of a release. Field duplicates taken for sample QA/QC showed detected values ranging from 0.4 mg/kg to 0.76 mg/kg from the same sample, indicating that the natural variation in minerological content ranges from slightly above to slightly below the negotiated background values.

No other inorganic contaminants exceeded background values.

3.1.2 Results of Monitoring Well Sampling

The results of the monitoring well sampling at Building 1414 show concentrations of the principal contaminants PCE, TCE, DCE, and vinyl chloride (VC) in the groundwater. PCE was detected in three of the groundwater samples, but all concentrations were below the maximum contaminant level (MCL). Figure E-5 shows that these PCE concentrations areconsistent with the mapped 1998 Compliance Plan data, which showed low to no-detected concentrations of PCE in the Building 1414 area. TCE was detected in all four groundwater samples. Concentrations of TCE ranged from 31 micrograms per liter (µg/L) to 640 µg/L. These TCE detections are also consistent with Compliance Plan mapping of TCE distributions in this area (Figure E-6). Total 1,2 DCE concentrations ranged from 19 µg/L to 340 µg/L. The DCE concentrations are also consistent with the 1998 Compliance Plan data (Figure E-7). VC was detected in one well, SS050MW468, at 12 µg/L (Figure E-8). This is the second detection of VC above the MCL in the vicinity of Building 1414.

In addition to these primary contaminants, low concentrations (less than 2 µg/L) of 1,1 DCA, 1,1 DCE, and chlorobenzene were detected in some of the groundwater samples (see Attachment B, Data Summary Tables).

No SVOCs were detected in any of the groundwater samples.

No groundwater samples had exceedences of the MCLs for metals.

3.2 Site S-10

From November 13 to December 8, 1998, three soil borings (SS045SB017 to SS045SB019) and two monitoring wells (SS050MW472 and SS050MW473) were installed at Site S-10. Total depths ranged from 24 feet to 28.5 feet, with an average depth of 25.6 feet. Soil samples from

the soil borings were analyzed for VOCs, SVOCs, and metals. Soil samples from monitoring well borings were analyzed for VOCs and metals only.

3.2.1 Results of Soil Sampling

Figure E-9 shows the VOC and SVOC detections in soil samples at Site S-10. PCE was detected in both soil samples collected from soil boring SS045SB017. This soil boring was located directly adjacent to monitoring well ST007MW053, where high concentrations of PCE have been detected in the groundwater. PCE was not detected in soil samples from either of the other two borings. Benzene, toluene, ethylbenzene, xylene, naphthalene, and 2-methylnaphthlene were detected in the 18- to 20-foot sample from soil boring SS045SB019. None of the detected constituents exceed TNRCC groundwater protection standards for soil. The results of these soil boring samples confirm that the PCE contamination at Site S-10 is localized in the vicinity of monitoring well ST007MW053.

Arsenic was detected in the 18- to 20-foot sample interval from SS050MW472 and SS050MW473 at 10.8J and 15.8J, respectively.

A total of five soil samples had detections of cadmium that exceeded background values. The maximum value detected was 2.4 mg/kg. These detections are considered to be of environmental or mineralogical origin and are not considered representative of a release. Field duplicates taken for sample QA/QC show detected values ranging from 0.4 mg/kg to 0.55 mg/kg from the same sample, indicating that the natural variation in mineralogical content can range from slightly above to slightly below the negotiated background values.

No other inorganic constituents exceeded background values.

3.2.2 Results of Groundwater Sampling

Groundwater samples were collected from monitoring wells SS050MW472 and SS050MW473. The only contaminant detected was benzene at 4 μg/L in SS050MW472. The localized nature of the S-10 PCE plume was confirmed by two facts: neither PCE nor TCE was detected in these two new monitoring wells, and historically, PCE has not been detected in the seven existing monitoring wells that surround ST007MW053 from 100 to 300 feet away.

No SVOCs were detected in any of the groundwater samples.

No groundwater samples had exceedences of the MCLs for metals.

3.3 Site SS050 Off-Base

From November 20 to December 15, 1998, 12 monitoring wells (SS050MW334 to SS050MW345) were installed off-base north and east of Zone 5. Total depths ranged from 23 to 44 feet, with an average depth of 34.5 feet. Following installation and development, one groundwater sample was collected from each monitoring well. Samples were analyzed for VOCs, SVOCs, and metals.

Of the 12 monitoring wells that were installed, only 1, SS050MW344, was dry. Two wells (SS050MW342 and SS050MW345) produced little groundwater and only VOC samples could be collected from them. VOCs, SVOCs, and metals were collected from all other wells.

3.3.1 Results of Groundwater Sampling

PCE was detected at 6 of the 12 off-base monitoring well locations. Concentrations ranged from 2 µg/L to 21 µg/L. The results of these samples were mapped in conjunction with the 1998 Compliance Plan data to provide a more complete picture of the off-base PCE distribution (Figure E-5). These additional groundwater data indicate Plume B is confined to the detection limit on the north, south, and west sides and down to the 5 µg/L contour, which is the MCL for PCE, on the east (down gradient) side. In addition, the results identified two other off-base PCE plumes. The smaller plume to the southeast, defined by monitoring well SS050MW334, appears to have low concentrations and limited areal extent. The larger plume, due east of Plume B, is not fully defined and appears to extend east, beyond the study area. Additional sampling being conducted under the Zone 4 RI may provide more information on the extent of this larger plume.

TCE was detected at 6 of the 12 off-base monitoring well locations. Concentrations ranged from 2 µg/L to 5 µg/L. These TCE concentrations were also mapped in conjunction with the 1998 Compliance Plan data to provide a more complete picture of the TCE distribution (Figure E-6). This additional off-base TCE data provides closure for Plume A to the detection limit on the north, south, and west sides, and to the 5µg/L contour on the east (down gradient) side.

DCE was detected at only one monitoring well, SS050MW338, at the detection limit (1 µg/L) (Figure E-7).

No VC was detected in the off-base groundwater samples.

In addition to PCE and TCE, other contaminants detected were benzene, toluene, and methyl ethyl ketone at monitoring well SS050MW345; benzene, acetone, and methyl ethyl ketone at monitoring well SS050MW342; and chloroform at monitoring well SS050MW335. Both concentrations of benzene were at the detection limit (1 µg/L); toluene was detected at a concentration of 2 µg/L, chloroform at 1 µg/L, acetone at 16µg/L, and methyl ethyl ketone at 8 µg/L and 10 µg/L. All secondary contaminant detections are localized and below their respective groundwater MCLs.

No SVOCs were detected in any of the groundwater samples.

No groundwater samples had exceedences of the MCLs for metals.

4.0 Summary and Conclusions

4.1 Building 1414

- All volatile and semivolatile organic contaminants detected in the soil samples are below TNRCC risk reduction standard 2 (RRS-2).
- Inorganic soil constituents are with an acceptable range of background values
- Contaminant detections are not high enough to be considered representative of concentrated source area.

- Groundwater concentrations of PCE, TCE, DCE, and VC are closely correlated to existing groundwater data in the area. PCE concentrations are below MCLs, while TCE, DCE, and VC are above MCLs.

4.2 Site S-10

- All volatile and semivolatile organic contaminants detected in the soil samples are below TNRCC RRS-2.
- Arsenic levels above background were detected in two soil samples. All other inorganic soil constituents are within an acceptable range of background values and are not considered representative of a release.
- No PCE or TCE was detected in groundwater samples from the newly installed monitoring wells. These non-detects, in addition to non-detects in seven other wells surrounding ST007MW053, confirm the localized occurrence of PCE in the groundwater at that monitoring well. Benzene, below the MCL, was detected in monitoring well SS050MW472.

4.3 Off-Base Groundwater

- The northern, southern, and western extents of Plume A (TCE) are defined to the detection limit. The eastern (downgradient) extent of Plume A is defined to the MCL (5 μg/L), which is approximately 5,000 feet east of the base boundary.
- The northern, southern, and western extents of Plume B (PCE) are also defined to the detection limit. The eastern extent (downgradient) is defined to the MCL (5 μg/L).
- The source and extent of two additional off-base PCE plumes are not fully defined.

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Attachment A
Soil Boring Logs and Well Construction Forms

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS025SB017 SB12-1	1 OF 1

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Flight Line West of Building 1414

ELEVATION N:569700.91 E:2134865.81 ELEV:695.04 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 22 ft bgs START 11-23-98 FINISH 11-23-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	SS-1 3"	2.0	—	0-2 ft: **SILTY ORGANIC CLAY (OH)**, black, moist, stiff, roots and sand size caliche throughout	OVM = 1355 Collect SIB018 from 0-2 ft for VOCs, SVOCs, and metals
	2-4	SS-2 2"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-2 ft	OVM = 0
5'	4-6	SS-3 3"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-4 ft	OVM = 0
	6-8	SS-4 2"	2.0	—	6-8 ft: **SILTY CLAY WITH SAND (CL)**, brown, dry, hard, iron stained with vugs of caliche	OVM = 0
	8-10	SS-5 3"	2.0	—	8-10 ft: **CLAYEY SILT (ML)**, brown, dry, hard, caliche in vugs, isolated caliche coatings on sand, iron staining	OVM = 0
10'	10-12	SS-6 2"	2.0	—	10-12 ft: **CLAYEY SILT (ML)**, as logged 8-10 ft	OVM = 0
	12-14	SS-7 3"	2.0	—	12-14 ft: **CLAYEY SILT (ML)**, as logged 8-12 ft	OVM = 0
15'	14-16	SS-8 2"	1.6	—	14-16 ft: **SAND WITH CLAY (SC)**, brown, dry, firm, iron stained, well sorted	OVM = 0
	16-18	SS-9 3"	0.4	—	16-18 ft: **GRAVEL WITH SAND (GP)**, brown, dry, hard, subrounded, limestone and chert gravel to .75"	OVM = 0 Gravel caused low recovery Rough drilling at 16.5 ft bgs
	18-20	SS-10 3"	0.3	—	18-20 ft: **GRAVEL WITH SAND (GP)**, as logged 16-18 ft, with increasing clay content	OVM = 0 Rough drilling
20'	20-22	SS-11 2"	0.8	—	20-22 ft: **GRAVEL WITH SAND (GP)**, as logged 16-20 ft	OVM = 0 Rough drilling 1515 Collect SIB019 from 20-22 ft for VOCs, SVOCs and metals
	22-24	SS-11 3"	0.5	—	22-24 ft: **GRAVEL WITH SAND (GP)**, as logged 16-22 ft	OVM = 0 Water table at 22 ft Perched water table
25'	24-26	SS-12 3"	0.4	—	24-26 ft: **GRAVEL WITH SAND (GP)**, as logged 16-24 ft, moist to wet	
	26-27	SS-13 2"	0.8	—	26-27 ft: **SILTY CLAY WITH GRAVEL (CL)**, olive brown, dry, hard	OVM borehole = 0/0/0 Navarro Transition
	27-28	SS-14 2"	1.0	—	27-28 ft: **SILTY CLAY(CL)**, olive brown, dry, hard, iron stained with black organics	OVM borehole = 0/0/0 Navarro Transition
30'					**Total Depth = 28 ft bgs**	

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS025SB018 SB12-12	1 OF 1

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION West of Fuel Management in Concrete

ELEVATION N:569279.01 E:2135044.02 ELEV:696.91 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 27 ft bgs START 12-1-98 FINISH 12-1-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	—	—	—	0-2 ft: **CONCRETE (NACM)**	OVM = 0/0/0 Cored out to 14 inches bgs, drilled out with HSA to 2 ft bgs
	2-4	SS-1 3"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, black, dry to moist, hard, sand size caliche throughout	OVM = 2.1 ppm 1335 Collect SIB021 from 2-4 ft for VOCs, SVOCs, and metals
5'	4-6	SS-2 2"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 2-4 ft	OVM = 3.8 ppm
	6-8	SS-3 3"	2.0	—	6-8 ft: **SILTY ORGANIC CLAY (OH)**, as logged 2-6 ft	OVM = 0 ppm
	8-10	SS-4 2"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, brown, dry, hard, caliche in vugs, iron stained	OVM = 1 ppm
10'	10-12	SS-5 3"	2.0	—	10-12 ft: **SILTY CLAY (CL)**, as logged 8-10 ft	OVM = 4.0 ppm 1440 Collect SIB022 from 10-12 ft for VOCs, SVOCs, and metals
	12-14	SS-6 2"	1.5	—	12-14 ft: **SILTY CLAY (CL)**, as logged 8-12 ft	OVM = 0 ppm
15'	14-16	SS-7 3"	2.0	—	14-16 ft: **SAND WITH CLAY AND SILT (SC)**, orangish brown, dry, firm to hard, iron stained, caliche coatings on larger sand grains	OVM = 0 ppm
	16-18	SS-8 2"	1.5	—	16-18 ft: **SAND WITH CLAY AND SILT (SC)**, as logged 14-16 ft	OVM = 0.ppm
20'	18-20	SS-9 3"	2.0	—	18-20 ft: **SAND WITH CLAY AND SILT (SC)**, as logged 14-18 ft, firm	OVM = 3 ppm
	20-22	SS-10 2"	1.0	—	20-22 ft: **SAND WITH CLAY AND SILT (SC)**, as logged 14-20 ft, firm	OVM = 0 ppm
	22-24	SS-11 3"	0.3	—	22-24 ft: **GRAVEL WITH CLAY (GC)**, brown, dry, hard, limestone and chert gravel to 1/2"	OVM = 0 ppm
25'	24-26	SS-12 2"	0.3	—	24-26 ft: **GRAVEL WITH SAND (GP)**, brown, moist, hard, limestone and chert gravel to 0.75", subrounded	OVM = 0 ppm
	26-28	SS-13 2"	0.2	—	26-28 ft: **GRAVEL WITH SAND (GP)**, as logged 24-26 ft	OVM = 0 ppm Water table at 27 ft
	28-29	SS-14 2"	1.0	—	28-29 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained with black organic material	OVM = 0 ppm Navarro Clay
30'					**Total Depth = 29 ft bgs**	

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS025SB019 SB12-3	1 OF 1

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION West Side of Building 1414

ELEVATION N:569550.76 E:2135198.84 ELEV:696.82 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE Dry START 12-9-98 FINISH 12-9-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	—	—	—	0-2 ft: **CONCRETE (NACM)**	OVM = 0/0/0
	2-4	SS-1 3"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, black, dry, hard, sand size caliche throughout	OVM = 0 ppm 1230 Collect SIB040 from 2-4 ft for VOCs, SVOCs, and metals
5'	4-6	SS-2 2"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 2-4 ft	OVM = 0 ppm
	6-8	SS-3 3"	2.0	—	6-8 ft: **SILTY ORGANIC CLAY (OH)**, as logged 2-6 ft	OVM = 0 ppm
	8-10	SS-4 2"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, brown, dry, hard, isolated sand 8-8.5 ft: vugs filled with caliche	OVM = 0 ppm
10'	10-12	SS-5 3"	2.0	—	10-12 ft: **SILTY CLAY (CL)**, as logged 8-10 ft	OVM = 0 ppm
	12-14	SS-6 2"	2.0	—	12-14 ft: **SILTY CLAY (CL)**, as logged 8-12 ft	OVM = 0 ppm
15'	14-16	SS-7 3"	0.1	—	14-16 ft: **CLAY WITH GRAVEL (CL)**, brown, dry, hard, chert gravel to 2"	OVM = 0 ppm Gravel caused low recovery
	16-18	SS-8 3"	1.0	—	16-18 ft: **GRAVEL WITH CLAY (GC)**, brown, dry, dard, subrounded limestone and chert gravel to 1.5"	OVM = 0 ppm
	18-20	SS-9 2"	0.8	—	18-20 ft: **GRAVEL WITH CLAY (GC)**, as logged 16-18 ft	OVM = 0 ppm
20'	20-22	SS-10 2"	0.7	—	20-22 ft: **GRAVEL WITH CLAY (GC)**, as logged 16-20 ft	OVM = 0 ppm
	22-24	SS-11 2"	0.3	—	22-24 ft: **GRAVEL WITH CLAY (GC)**, as logged 16-22 ft	OVM = 0 ppm Gravel caused by low recovery
25'	24-26	SS-12 2"	0.9	—	24-26 ft: **SILT WITH CLAY (ML)**, brown to gray, dry, hard, iron stained, caliche in vugs, isolated gravel	OVM = 0 ppm Not Navarro
	26-28	SS-13 2"	1.0	—	26-28 ft: **SILT WITH CLAY (ML)**, as logged 24-26 ft	OVM = 0 ppm 1500 Collect SIB041 from 26-28 ft for VOCs, SVOCs, and metals
	28-30	SS-14 2"	2.0	—	28-30 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained, gypsum crystals	OVM = 0 ppm Navarro Clay
30'						

Total Depth = 30 ft bgs

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS025SB020 SB12-4	1 OF 1

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION East of Building 1414

ELEVATION N:569601.40 E:2135447.01 ELEV:696.04 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT 8-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 24 ft bgs START 12-3-98 FINISH 12-3-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	—	—	—	0-2 ft: **ASPHALT AND BASE (NACM)**	OVM = 0/0/0 Drilled through asphalt and base to 2 ft bgs
	2-4	SS-1 3"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, black, dry, hard, sand size caliche throughout	OVM = 0 ppm 0825 Collect SIB025 from 2-4 ft for VOCs, SVOCs, and metals
5'	4-6	SS-2 2"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 2-4 ft	OVM = 0 ppm
	6-8	SS-3 3"	2.0	—	6-8 ft: **SILTY ORGANIC CLAY (OH)**, as logged 2-6 ft	OVM = 0 ppm
	8-10	SS-4 2"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, brown, dry, hard, vugs filled with caliche, isolated sand with caliche coatings	OVM = 0 ppm
10'	10-12	SS-5 3"	2.0	—	10-12 ft: **SILTY CLAY (CL)**, as logged 8-10 ft	OVM = 0 ppm
	12-14	SS-6 2"	1.7	—	12-14 ft: **CLAYEY SILT (ML)**, brown, dry, hard, black organics and caliche in vugs	OVM = 0 ppm
15'	14-16	SS-7 3"	2.0	—	14-16 ft: **SAND WITH CLAY (SC)**, light brown, dry, hard, limestone sand subrounded and well graded	OVM = 0 ppm
	16-18	SS-8 2"	1.8	—	16-18 ft: **GRAVEL WITH CLAY (SC)**, as logged 14-16 ft, with chert gravel 17.5-18 ft, subrounded to 1"	OVM = 0 ppm
	18-20	SS-9 3"	0.7	—	18-20 ft: **GRAVEL WITH CLAY (SC)**, as logged 14-18 ft, with chert gravel to 1.0", moist	OVM = 0 ppm
20'	20-22	SS-10 2"	0.3	—	20-22 ft: **GRAVEL WITH CLAY (GC)**, brown, moist, hard, limestone and chert gravel to 1.5", subangular	OVM = 0 ppm Gravel causing low recovery
	22-24	SS-11 2"	0.3	—	22-24 ft: **GRAVEL WITH CLAY (GC)**, as logged 20-22 ft	OVM = 0 ppm Gravel causing low recovery 0955 Collect SIB026 from 22-24 ft for VOCs, SVOCs, and metals
25'	24-26	SS-12 2"	0.5	—	24-26 ft: **GRAVEL WITH CLAY (GC)**, as logged 20-24 ft, wet	OVM = 0 ppm Water Table at 24 ft bgs Rough drilling
	26-28.5	—	—	—	26-28 ft: **GRAVEL (GP)**, brown, wet, hard, subrounded limestone and chert gravel to 1.5"	OVM = 0 ppm Drilling through gravels to top of Na. Logged from cuttings
30'	28.5-30	SS-14 2"	2.0	—	28.5-30 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained	OVM = 0 ppm Navarro Clay

Total Depth = 30 ft bgs

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS025SB021 SB12-5	1 OF 1

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION East Side of Building 1414

ELEVATION N:569379.01 E:2135408.42 ELEV:696.63 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE Dry START 12-3-98 FINISH 12-3-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	—	—	—	0-2 ft: **ASPHALT AND BASE (NACM)**	OVM = 0
	2-4	SS-1 3"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, black, dry, hard, sand size caliche throughout	OVM = 0 ppm
5'	4-6	SS-2 2"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 2-4 ft	OVM = 0 ppm
	6-8	SS-3 3"	2.0	—	6-8 ft: **SILTY ORGANIC CLAY (OH)**, as logged 2-6 ft	OVM = 0 ppm 1235 Collect SIB027 from 6-8 ft for VOCs, SVOCs, and metals
10'	8-10	SS-4 2"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, brown, dry, hard, vugs of caliche	OVM = 0 ppm
	10-12	SS-5 3"	2.0	—	10-12 ft: **SILTY CLAY (CL)**, as logged 8-10 ft	OVM = 0 ppm
	12-14	SS-6 2"	2.0	—	12-14 ft: **SILTY CLAY (CL)**, as logged 8-12 ft	OVM = 0 ppm
15'	14-16	SS-7 3"	2.0	—	14-16 ft: **CLAYEY SILT (ML)**, brown, dry, hard, vugs of caliche and black organics	OVM = 0 ppm
	16-18	SS-8 2"	1.6	—	16-18 ft: **CLAYEY SILT (ML)**, as logged 14-16 ft	OVM = 0 ppm
	18-20	SS-9 3"	2.0	—	18-20 ft: **CLAYEY SILT (ML)**, as logged 14-18 ft	OVM = 0 ppm
20'	20-22	SS-10 2"	2.0	—	20-22 ft: **CLAYEY SILT (ML)**, as logged 14-20 ft, with increasing sand	OVM = 0 ppm
	22-24	SS-11 3"	0.9	—	22-24 ft: **CLAYEY SILT (ML)**, as logged 14-22 ft, with gravel 23.5-24 ft	OVM = 0 ppm
25'	24-26	SS-12 2"	1.3	—	24-26 ft: **CLAYEY SILT (ML)**, as logged 14-24 ft, light gray	OVM = 0 ppm
	26-28	SS-13 3"	1.2	—	26-28 ft: **SAND WITH CLAY (SC)**, light gray, dry, hard, isolated limestone gravel to 1.5" subrounded	OVM = 0 ppm 1420 Collect SIB028 from 26-28 ft for VOCs, SVOCs, and metals
	28-29	SS-14 2"	1.8	—	28-30 ft: **SILTY CLAY (CL)**, olive gray, hard, dry, black organics	OVM = 0 ppm Navarro Clay
30'					Total Depth = 30 ft bgs	

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS025SB022 SB12-6	1 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Southeast of Building 1414

ELEVATION N:569271.40 E:2135397.70 ELEV:695.89 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 24 ft bgs START 12-3-98 FINISH 12-3-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	—	—	—	0-2 ft: **ASPHALT AND BASE (NACM)**	OVM = 0 ppm
	2-4	SS-1 3"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, black, dry, hard, sand size caliche throughout interval	OVM = 0 ppm
5'	4-6	SS-2 2"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 2-4 ft	OVM = 0 ppm
	6-8	SS-3 3"	2.0	—	6-8 ft: **SILTY ORGANIC CLAY (OH)**, as logged 2-6 ft	OVM = 0 ppm 1540 Collect SIB029 from 6-8 ft for VOCs, SVOCs, and metals
10'	8-10	SS-4 2"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, brown, dry, hard, vugs filled with caliche, isolated limestone sand	OVM = 0 ppm
	10-12	SS-5 3"	2.0	—	10-12 ft: **SILTY CLAY (CL)**, as logged 8-10 ft	OVM = 0 ppm
	12-14	SS-6 2"	2.0	—	12-14 ft: **SILTY CLAY (CL)**, as logged 8-12 ft	OVM = 0 ppm
15'	14-16	SS-7 3"	2.0	—	14-16 ft: **SILTY CLAY (CL)**, as logged 8-14 ft	OVM = 0 ppm
	16-18	SS-8 2"	1.1	—	16-18 ft: **SILTY CLAY (CL)**, as logged 8-16 ft, with gravel 17.5-18 ft	OVM = 0 ppm
	18-20	SS-9 3"	0.5	—	18-20 ft: **SILT WITH GRAVEL (ML)**, brown, dry, hard, limestone gravel subrounded to 1"	OVM = 0 ppm Isolated limestone gravel caused low recovery
20'	20-22	SS-10 3"	1.1	—	20-22 ft: **SILT WITH GRAVEL (ML)**, as logged 18-20 ft, light brown to gray with iron stains	OVM = 0 ppm
	22-24	SS-11 2"	0.4	—	22-24 ft: **SILT WITH GRAVEL (ML)**, as logged 18-22 ft	OVM = 0 ppm 1635 Collect SIB030 from 22-24 ft for VOCs, SVOCs, and metals
25'	24-26	SS-12 3"	0.6	—	24-26 ft: **WELL GRADED GRAVEL (GP)**, brown, wet, hard, subrounded limestone and chert gravel to 1"	OVM = 0 ppm Water Table at 24 ft bgs Gravel caused low recovery
	26-30	—	—	—	26-30 ft: **WELL GRADED GRAVEL (GP)**, as logged 24-26 ft	OVM borehole = 0/0/0 ppm Drilling through gravels Logged from cuttings
30'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS025SB022 SB12-6	2 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Southeast of Building 1414

ELEVATION N:569271.40 E:2135397.70 ELEV:695.89 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 24 ft bgs START 12-3-98 FINISH 12-3-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'	30-31	SS-13 2"	1.0	—	30-31 ft: **SILTY CLAY (CL)**, olive gray, hard, dry, iron stained	Navarro Clay at 30 ft bgs
					Total Depth = 31 ft bgs	
35'						
40'						
45'						
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS025SB023 SB12-7	1 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION 100 Yards South of Building 1414

ELEVATION N:569127.21 E:2135381.98 ELEV:694.77 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 24.5 ft bgs START 11-12-98 FINISH 11-12-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	SS-1 3"	2.0	—	0-2 ft: **SILTY ORGANIC CLAY (OH)**, black, dry to moist, hard to stiff, roots and sand size caliche throughout interval	OVM = 0 ppm
	2-4	SS-2 3"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-2 ft	OVM = 0 ppm
5'	4-6	SS-3 2"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-4 ft	OVM = 0 ppm
	6-8	SS-4 3"	2.0	—	6-8 ft: **SILTY CLAY (CL)**, brown, dry, hard, vugs of caliche, iron stained	OVM = 0 ppm 0830 Collect SIB009 (with MS/MSD) and SIB010FD1from 6-8 ft for VOCs, SVOCs, and metals
	8-10	SS-5 2"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, as logged 6-8 ft	OVM = 0 ppm
10'	10-12	SS-6 3"	2.0	—	10-12 ft: **SILTY CLAY (CL)**, as logged 6-10 ft	OVM = 0 ppm
	12-14	SS-7 2"	2.0	—	12-14 ft: **SILTY CLAY (CL)**, as logged 6-12 ft	OVM = 0 ppm
15'	14-16	SS-8 3"	2.0	—	14-16 ft: **SANDY CLAY (CL)**, brown, dry, hard, subangular sand, black organics	OVM = 0 ppm
	16-18	SS-9 2"	1.5	—	16-18 ft: **SANDY CLAY (CL)**, as logged 14-16 ft, with sand	OVM = 0 ppm
	18-20	SS-10 3"	0.5	—	18-20 ft: **CLAY WITH SAND AND GRAVEL (CL)**, light brown, dry, hard, subrounded limestone and chert sand to 1"	OVM = 0 ppm
20'	20-22	SS-11 3"	0.5	—	20-22 ft: **SAND WITH GRAVEL AND CLAY (SC)**, light brown, dry, hard, subrounded limestone and chert to 1" with black organics	OVM = 0 ppm
	22-24	SS-12 3"	0.5	—	22-24 ft: **SAND WITH GRAVEL AND CLAY (SC)**, as logged 20-22 ft, with gravel increasing to~10%	OVM = 0 ppm 0935 Collect SIB011 from 22-24 ft for VOCs, SVOCs, and metals
25'	24-26	SS-13 3"	0.5	—	24-26 ft: **SAND WITH GRAVEL AND CLAY (SC)**, as logged 20-24 ft, decreasing gravel at 25.5 ft	OVM = 0 ppm Smoother drilling at 25.5 ft
	26-28	—	—	—	26-28 ft: **NAVARRO TRANSITION AS LOGGED FROM CUTTINGS (CL)**, olive brown silty clay with iron staining and isolated gravel	Rough drilling stopped OVM borehole = 0/0/0 Water table ~24.5 ft bgs Will drill through gravels to Navarro because all samples for analysis have been collected, will complete log from cuttings
30'	28-32	—	—	—	28-32 ft: **NAVARRO CLAY**, driller notes change at ~28 ft, sample with split spoon 30-32 ft and confirm Navarro Clay	

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS025SB023 SB12-7	2 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION 100 Yards South of Building 1414

ELEVATION N:569127.21 E:2135381.98 ELEV:694.77 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 24.5 ft bgs START 11-12-98 FINISH 11-12-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE: INTERVAL	SAMPLE: TYPE AND NUMBER	SAMPLE: RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'					SILTY CLAY (CL), olive brown, dry, hard, iron stained, black organics	
					Total Depth = 32 ft bgs	
35'						
40'						
45'						
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS025SB024 SB12-8	1 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION East Side of Building 1414

ELEVATION N:569537.81 E:2135487.79 ELEV:694.94 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT 8-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 22 ft bgs START 11-11-98 FINISH 11-11-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'						
	0-2	SS-1 3"	1.3	—	0-2 ft: **SILTY ORGANIC CLAY (OH)**, black, moist, hard, sand size caliche and roots throughout	OVM = 0 ppm
	2-4	SS-2 2"	1.7	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-2 ft	OVM = 0 ppm
5'	4-6	SS-3 3"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-4 ft	OVM = 0 ppm
	6-8	SS-4 2"	2.0	—	6-8 ft: **SILTY CLAY (CL)**, brown, moist, hard, iron stained with vugs of caliche	OVM = 0 ppm 0950 Collect SIB044 from 4-6 ft for VOCs, SVOCs, and metals (Bottom of Sewer)
	8-10	SS-5 3"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, as logged 6-8 ft	OVM = 0 ppm
10'	10-12	SS-6 2"	1.2	—	10-12 ft: **SILTY CLAY (CL)**, as logged 6-10 ft, with isolated gravel (<5%), chert to 1.5"	OVM = 0 ppm One piece of chert caused decreased recovery
	12-14	SS-7 3"	2.0	—	12-14 ft: **CLAYEY SILT (ML)**, light brown, moist to dry, no caliche	OVM = 0 ppm
15'	14-16	SS-8 2"	2.0	—	14-16 ft: **CLAYEY SILT (ML)**, as logged 12-14 ft, <1% subrounded limestone to 1/2"	OVM = 0 ppm
	16-18	SS-9 3"	2.0	—	16-18 ft: **CLAY WITH GRAVEL (CL)**, brown, dry to moist, hard, limestone and chert gravel to 2"	OVM = 0 ppm
	18-20	SS-10 2"	2.0	—	18-20 ft: **CLAY WITH GRAVEL (CL)**, as logged 16-18 ft, decreasing gravel content	OVM = 0 ppm
20'	20-22	SS-11 3"	2.0	—	20-22 ft: **GRAVEL WITH CLAY (GC)**, moist to dry, brown, hard, limestone and chert gravel to 2"	OVM = 0 ppm 1110 Collect SIB005 from 20-22 ft for VOCs, SVOCs, and metals
	22-24	SS-12 3"	1.1	—	22-24 ft: **GRAVEL WITH CLAY (GC)**, as logged 20-22 ft, gravel increasing in size to 2.5"	OVM = 0 ppm Water Table at 22 ft bgs
25'	24-28	—	—	—	24-28 ft: **GRAVEL WITH CLAY (GC)**, as logged 20-24 ft	OVM borehole = 0/0/0 ppm Because no samples are being taken from below the water table, will drill through gravels to Navarro. Logged from cuttings 24-28 ft Rough drilling indicates gravel
	28-30	SS-13 2"	1.1	—	28-30 ft: **SANDY SILT (ML)**, greenish orange, dry to moist, glauconite	Change from rough to smooth drilling. Will check for Navarro with spoon.
30'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS025SB024 SB12-8	2 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION East Side of Building 1414

ELEVATION N:569537.81 E:2135487.79 ELEV:694.94 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 22 ft bgs START 11-11-98 FINISH 11-11-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'	30-32	—	—	—	30-32 ft: **SANDY SILT (ML)**, as logged 28-30 ft, based on cuttings	OVM borehole = 0/0/0 Well located ~30 ft southeast of boring has total depth = 35 ft, therefore Navarro is estimated at ~33 ft bgs
	32-34	SS-14 2"	2.0	—	32-34 ft: **SILTY CLAY (CL)**, olive green with mottling, dry, hard, glauconite sand (<10%), Navarro CLay	Will sample with spoon at 32 ft to check for Navarro surface OVM = 0 ppm
					Total Depth = 34 ft bgs	
35'						
40'						
45'						
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS025SB024 SB12-8	2 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION East Side of Building 1414

ELEVATION N:569537.81 E:2135487.79 ELEV:694.94 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 22 ft bgs START 11-11-98 FINISH 11-11-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'	30-32	—	—	—	30-32 ft: **SANDY SILT (ML)**, as logged 28-30 ft, based on cuttings	OVM borehole = 0/0/0 Well located ~30 ft southeast of boring has total depth = 35 ft, therefore Navarro is estimated at ~33 ft bgs
	32-34	SS-14 2"	2.0	—	32-34 ft: **SILTY CLAY (CL)**, olive green with mottling, dry, hard, glauconite sand (<10%), Navarro CLay	Will sample with spoon at 32 ft to check for Navarro surface OVM = 0 ppm
					Total Depth = 34 ft bgs	
35'						
40'						
45'						
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS025SB025 SB12-9	2 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Southeast of Building 1414

ELEVATION N:569359.92 E:2135470.73 ELEV:694.83 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 22.5 ft bgs START 11-11-98 FINISH 11-11-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'	30-32	—	—	—	30-32 ft: **GRAVEL WITH CLAY (GC)**, as logged 27-30 ft, from cuttings	OVM borehole = 0/0/0 Rough drilling
	32-34	—	—	—	32-33 ft: **GRAVEL WITH CLAY (GC)**, as logged 27-32 ft 33-34 ft: **SILTY CLAY (CL)**, olive brown, hard, dry, (Navarro)	Smoother drilling ~ 33 ft Will run spoon at 34-36 ft to check for Navarro
35'	34-36	SS-13 2"	2.0	—	34-36 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained, black organics (Navarro)	OVM = 0 ppm Navarro will be noted at 33 ft when drilling became smooth
					Total Depth = 36 ft bgs	
40'						
45'						
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS025SB026 SB12-10	1 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION West Side of Fuels Mgt.

ELEVATION N:569298.22 E:2135099.65 ELEV:696.55 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE Dry START 12-9-98 FINISH 12-9-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS - DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	—	—	—	0-2 ft: **CONCRETE (NACM)**	OVM = 0 ppm
	2-4	SS-1 3"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, black, dry, hard, sand sized caliche throughout	OVM = 0 ppm
5'	4-6	SS-2 3"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 2-4 ft	OVM = 0 ppm
	6-8	SS-3 2"	2.0	—	6-8 ft: **SILTY ORGANIC CLAY (OH)**, as logged 2-6 ft	OVM = 1.6 ppm 0800 Collect SIB042 from 6-8 ft for VOCs, SVOCs, and metals Approximate depth of bottom sewer line at 6 ft bgs
10'	8-10	SS-4 2"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, brown, dry, hard, vugs filled with caliche	OVM = 13 ppm
	10-12	SS-5 2"	2.0	—	10-12 ft: **SILTY CLAY (CL)**, as logged 8-10 ft	OVM = 3 ppm
	12-14	SS-6 3"	2.0	—	12-14 ft: **SILTY CLAY (CL)**, as logged 8-12 ft	OVM = 11 ppm 0915 Collect SIB043 from 12-14 ft for VOCs, SVOCs, and metals
15'	14-16	SS-7 2"	2.0	—	14-16 ft: **SILTY CLAY (CL)**, as logged 8-14 ft, with gravel 14.5-15 ft	OVM = 7 ppm
	16-18	SS-8 3"	0.8	—	16-18 ft: **GRAVEL WITH CLAY (GC)**, brown, dry, hard, limestone and chert gravel to 2" subrounded	OVM = 0 ppm
20'	18-20	SS-9 2"	1.0	—	18-20 ft: **GRAVEL WITH CLAY (GC)**, as logged 16-18 ft	OVM = 0 ppm
	20-22	SS-10 2"	0.9	—	20-22 ft: **GRAVEL WITH CLAY (GC)**, as logged 16-20 ft	OVM = 0 ppm
	22-24	SS-11 2"	2.0	—	22-24 ft: **SILT WITH CLAY (ML)**, light brown, dry, hard, iron stained, isolated subrounded limestone gravel to 1/2"	OVM = 0 ppm
25'	24-26	SS-12 2"	2.0	—	24-26 ft: **SILT WITH CLAY (ML)**, as logged 22-24 ft	OVM = 0 ppm
	26-28	SS-13 2"	2.0	—	26-28 ft: **CLAY WITH SILT (CL)**, brown, hard, dry, isolated limestone gravel subrounded	OVM = 0 ppm Navarro Transition
30'	28-30	SS-14 2"	2.0	—	28-30 ft: **CLAY WITH GRAVEL AND SAND (CL)**, brown to gray, dry, hard, subrounded limestone and chert to 1"	OVM = 0 ppm Navarro Transition

CH2MHILL

PROJECT NUMBER	BORING NUMBER	
111494.B1.20	SS025SB026 SB12-10	SHEET 2 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION West Side of Fuels Mgt.

ELEVATION N:569298.22 E:2135099.65 ELEV:696.55 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT 8-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE Dry START 12-9-98 FINISH 12-9-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'	30-32	SS-14 2"	2.0	—	30-32 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained, gypsum crystals	OVM = 0 Navarro Clay
					Total Depth = 32 ft bgs	
35'						
40'						
45'						
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS025SB027 SB12-14	1 OF 1

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION 150 Yards Southwest of Building 1414

ELEVATION N:569233.42 E:2135102.40 ELEV:696.26 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 29 ft bgs START 11-12-98 FINISH 11-12-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	SS-1 3"	1.1	—	0-2 ft: **SILTY ORGANIC CLAY (OH)**, black	OVM = 0 ppm
	2-4	—	—	—	2-4 ft: **FILL (NACM)**, gravel, backfill	OVM = 0 ppm Drilled out, logged 2-4 ft from cuttings, not native soil
5'	4-6	—	—	—	4-6 ft: **FILL (NACM)**, as logged 2-4 ft	OVM = 0 ppm Cannot drive spoon, too much gravel backfill
	6-8	—	—	—	6-8 ft: **FILL (NACM)**, as logged 2-6 ft	OVM = 0/0/0 Logged from cuttings, too much gravel fill to drive spoon
10'	8-12	Drilled Out	—	—	8-12 ft: **FILL (NACM)**, as logged 2-8 ft	OVM = 0/0/0 Too much gravel backfill to drive spoon, logged from cuttings
	12-14	SS-2 3"	—	—	12-14 ft: **FILL (NACM)**, as logged 2-12 ft, decreasing gravel, probably close to end of backfill	OVM = 0/0/0 Gravel backfill and clay mixture in cuttings. Decreasing gravel
15'	14-16	SS-3 3"	2.0	—	14-16 ft: **SILTY CLAY (CL)**, brown, dry, hard, isolated subrounded limestone and chert to 1/2"	OVM = 300 ppm 1540 Collect SIB014 from 14-16 ft for VOCs, SVOCs, and metals
	16-18	SS-4 3"	2.0	—	16-18 ft: **SILTY CLAY (CL)**, as logged 14-16 ft	OVM = 143 ppm
	18-20	SS-5 3"	1.3	—	18-19 ft: **SILTY CLAY (CL)**, as logged 14-18 ft 19-20 ft: **GRAVEL WITH CLAY (GC)**, light brown, dry, hard, subrounded limestone and chert gravel to 2"	OVM = 172 ppm
20'	20-22	SS-6 3"	2.0	—	20-22 ft: **CLAY WITH GRAVEL (CL)**, brown, dry, hard, black organics, subrounded limestone and chert to 1.5"	OVM = 248 ppm
	22-24	SS-7 3"	0.4	—	22-24 ft: **GRAVEL WITH CLAY (GC)**, brown, dry, hard, subrounded limestone and chert gravel	OVM = 175 ppm Hard to drive spoon
25'	24-26	SS-8 3"	0.5	—	24-26 ft: **GRAVEL WITH CLAY (GC)**, as logged 22-24 ft	OVM = 75 ppm
	26-28	SS-9 3"	0.3	—	26-28 ft: **GRAVEL WITH CLAY (GC)**, as logged 22-24 ft, still no water table	OVM = 70 ppm 1645 Collect SIB015 from 26-28 ft. VOCs, SVOCs, and metals
30'	28-30	SS-10 2"	2.0	—	28-30 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained (Navarro Clay)	OVM = 0 ppm Slight water table at top of sample Water table is very thin and probably at ~29 ft bgs

Total Depth = 30 ft

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.81.20	SS025SB028 SB12-15	1 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION South Side of Building 1416

ELEVATION N:569216.30 E:2135244.64 ELEV:695.46 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 22 ft bgs START 11-12-98 FINISH 11-12-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	SS-1 3"	2.0	—	0-2 ft: **SILTY ORGANIC CLAY (OH)**, black, dry to moist, hard, roots and sand size caliche throughout	OVM = 0 ppm
	2-4	SS-2 2"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-2 ft	OVM = 0 ppm
5'	4-6	SS-3 3"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-4 ft	OVM = 0 ppm
	6-8	SS-4 2"	2.0	—	6-8 ft: **SILTY CLAY (CL)**, brown, dry, hard, iron stained, caliche in vugs, isolated roots, black organics	OVM = 0 ppm 1115 Collect SIB012 from 6-8 ft for VOCs, SVOCs, and metals
	8-10	SS-5 3"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, as logged 6-8 ft	OVM = 0 ppm
10'	10-12	SS-6 2"	2.0	—	10-12 ft: **SILTY CLAY (CL)**, as logged 6-10 ft	OVM = 0 ppm
	12-14	SS-7 3"	2.0	—	12-14 ft: **SILTY CLAY (CL)**, as logged 6-12 ft	OVM = 0 ppm
15'	14-16	SS-8 2"	2.0	—	14-16 ft: **SILTY CLAY (CL)**, as logged 6-14 ft, with gravel 15.75-16 ft	OVM = 0 ppm
	16-18	SS-9 3"	0.5	—	16-18 ft: **GRAVEL WITH CLAY (GC)**, brown, dry, hard, subrounded limestone and chert gravel to 1.5"	OVM = 0 ppm
	18-20	SS-10 3"	0.5	—	18-20 ft: **GRAVEL WITH CLAY (GC)**, as logged 16-18 ft	OVM = 0 ppm
20'	20-22	SS-11 3"	0.6	—	20-22 ft: **GRAVEL WITH CLAY (GC)**, as logged 16-20 ft	OVM = 0 ppm 1330 Collect SIB013 from 20-22 ft for VOCs, SVOCs, and metals
25'	22-30	—	—	—	22-30 ft: **GRAVEL WITH CLAY AND SAND (GC)**, brown, hard, wet, black organics	OVM borehole = 0/0/0 Water Table at 22 ft bgs Will log remainder of boring from cuttings and the way the augers are drilling Hard drilling at 25 ft, still in gravels
30'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS025SB028 SB12-15	2 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION South Side of Building 1416

ELEVATION N:569216.30 E:2135244.64 ELEV:695.46 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 22 ft bgs START 11-12-98 FINISH 11-12-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'	30-33	—	—	—	30-33 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained, black organics in vugs	OVM borehole = 0/0/0 Smooth drilling at 30 ft Sampling with split spoon to check for Navarro Navarro at 30 ft
					Total Depth = 33 ft bgs	
35'						
40'						
45'						
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SSD45SB017 SB12-11	1 OF 1

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION By Hanger At Base-Ops

ELEVATION N:563929.33 E:2135717.13 ELEV:679.94 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 21 ft bgs START 12-8-98 FINISH 12-8-98 LOGGER B. Rabe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	—	—	—	0-2 ft: **ASPHALT AND BASE (NACM)**	OVM = 0 ppm Drilled through asphalt and base to 2 ft
	2-4	SS-1 3"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, black, dry, hard, sand sized caliche throughout	OVM = 0 ppm 1450 Collect SIB032 and SIB033FD1 from 2-4 ft for VOCs, SVOCs, and metals
5'	4-6	SS-2 2"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 2-4 ft	OVM = 0 ppm
	6-8	SS-3 3"	2.0	—	6-8 ft: **SILTY CLAY (CL)**, brown, dry, hard, vugs with caliche, isolated sand with caliche coatings	OVM = 0 ppm
	8-10	SS-4 2"	0.4	—	8-10 ft: **SILTY CLAY (CL)**, as logged with increasing gravel content	OVM = 0 ppm
10'	10-12	SS-5 2"	0.4	—	10-12 ft: **GRAVEL WITH CLAY (GC)**, brown, dry, hard, limestone and chert gravel subrounded to 1.5"	OVM = 0 ppm
	12-14	SS-6 3"	2.0	—	12-14 ft: **CLAY WITH SILT (CL)**, light brown, dry, hard, iron stained, with isolated gravel	OVM = 0 ppm
15'	14-16	SS-7 2"	2.0	—	14-16 ft: **CLAY WITH SILT (CL)**, as logged 12-14 ft	OVM = 0 ppm
	16-18	SS-8 2"	2.0	—	16-18 ft: **CLAY WITH SILT (CL)**, as logged 12-16 ft	OVM = 0 ppm
	18-20	SS-9 3"	0.4	—	18-20 ft: **GRAVEL WITH CLAY (GC)**, brown, dry, hard, limestone gravel subrounded	OVM = 0 ppm
20'	20-22	SS-10 3"	0.5	—	20-22 ft: **GRAVEL WITH CLAY (GC)**, as logged 18-20 ft, water table at 21 ft bgs	OVM = 0 1600 Collect SIB034 from 20-21 ft for VOCs, SVOCs and metals Water table at 21 ft
	22-24	SS-11 2"	2.0	—	22-24 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained	OVM = 0 Navarro Clay
25'					**Total Depth = 24 ft bgs**	
30'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS045SB018 SB12-12	1 OF 1

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION By Base-Ops

ELEVATION N:563928.10 E:2135761.53 ELEV:681.02 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE Dry START 12-8-98 FINISH 12-8-98 LOGGER S. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION	COMMENTS
0'					SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	0-2	SS-1 3"	2.0	—	0-2 ft: **SILTY ORGANIC CLAY (OH)**, black, dry, hard, roots and sand size caliche throughout	OVM = 0 ppm 1035 Collect SIB035 from 0-2 ft for VOCs, SVOCs, and metals
	2-4	SS-2 2"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-2 ft	OVM = 0 ppm
5'	4-6	SS-3 3"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-4 ft	OVM = 0 ppm
	6-8	SS-4 2"	2.0	—	6-8 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-6 ft	OVM = 0 ppm Clay very hard resulting in slow drilling
	8-10	SS-5 3"	1.2	—	8-10 ft: **SILTY CLAY (CL)**, brown, dry, hard, vugs filled with caliche, isolated caliche coated sand	OVM = 0 ppm
10'	10-12	SS-6 2"	0.3	—	10-12 ft: **GRAVEL WITH CLAY (GC)**, brown, dry, hard, limestone and chert gravel subrounded to 1"	OVM = 0 ppm
	12-14	SS-7 2"	0.3	—	12-14 ft: **GRAVEL WITH CLAY (GC)**, logged 10-12 ft	OVM = 0 ppm
15'	14-16	SS-8 2"	2.0	—	14-16 ft: **SILT WITH CLAY (ML)**, brown, dry, hard, isolated gravel subrounded	OVM = 0 ppm
	16-18	SS-9 3"	2.0	—	16-18 ft: **SILT WITH CLAY (ML)**, as logged 14-16 ft	OVM = 0.ppm
	18-20	SS-10 2"	2.0	—	18-20 ft: **SILT WITH CLAY (ML)**, as logged 14-18 ft	OVM = 0 ppm
20'	20-22	SS-11 3"	1.0	—	20-22 ft: **SILT WITH CLAY (ML)**, as logged 14-20 ft, with sand	OVM = 0 1400 Collect SIB036 from 20-22 ft for VOCs, SVOCs and metals
	22-24	SS-12 2"	2.0	—	22-24 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained	OVM = 0 Navarro Clay
25'					**Total Depth = 24 ft bgs**	
30'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS045SB019 SB12-13	1 OF 1

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION By Base-Ops

ELEVATION N:563832.61 E:2135792.89 ELEV:679.24 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT 6-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 20 ft bgs START 12-8-98 FINISH 12-8-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	SS-1 3"	2.0	—	0-2 ft: **SILTY ORGANIC CLAY (OH)**, black, dry, hard, roots and sand size caliche throughout	OVM = 0 ppm
	2-4	SS-2 2"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-2 ft	OVM = 0 ppm
5'	4-6	SS-3 3"	2.0	—	4-6 ft: **SILTY CLAY (CL)**, brown, dry, hard, sand with caliche coatings 4-4.5 ft	OVM = 9 ppm 0915 Collect SIB037 from 4-6 ft for VOCs, SVOCs, and metals
	6-8	SS-4 2"	2.0	—	6-8 ft: **SILTY CLAY (CL)**, as logged 4-6 ft	OVM = 0 ppm
	8-10	SS-5 3"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, as logged 4-8 ft	OVM = 0 ppm
10'	10-12	SS-6 2"	2.0	—	10-12 ft: **SILTY CLAY (CL)**, as logged 4-10 ft	OVM = 0 ppm
	12-14	SS-7 3"	0.9	—	12-14 ft: **CLAY WITH GRAVEL (CL)**, gray, dry, hard, subrounded limestone gravel to 1"	OVM = 2 ppm
15'	14-16	SS-8 2"	0.3	—	14-16 ft: **CLAY WITH GRAVEL (CL)**, as logged 12-14 ft	OVM = 1 ppm
	16-18	SS-9 3"	0.5	—	16-18 ft: **CLAY WITH GRAVEL (CL)**, as logged 12-16 ft	OVM = 32 ppm
	18-20	SS-10 3"	0.4	—	18-20 ft: **CLAY WITH GRAVEL (CL)**, as logged 12-18 ft	OVM = 250 ppm 0930 Collect SIB038 from 18-20 ft for VOCs, SVOCs, and metals
20'	20-22	SS-11 3"	0.3	—	20-22 ft: **WELL GRADED GRAVEL (GP)**, brown to gray, wet, hard	OVM = 0 Water table at 20 ft
	22-25	—	—	—	22-24 ft: **WELL GRADED GRAVEL (GP)**, as logged 20-22 ft, wet 24-25 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained	OVM borehole = 0/0/0 Logged from cuttings
25'					**Total Depth = 25 ft bgs**	
30'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW334 MW12-4	1 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Marlow Between Nightengale and Ballard

ELEVATION N:566088.29 E:2141427.48 ELEV:677.80 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 28 ft bgs START 11-16-98 FINISH 11-16-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-1	—	—	—	0-1 ft: **ASPHALT AND ROAD BASE (NACM)**	OVM = 0 ppm Asphalt to road base, drilled to 1 ft then started sample
	1-3	SS-1 3"	2.0	—	1-3 ft: **SILTY ORGANIC CLAY (OH)**, black, moist, hard, sand size caliche and roots throughout	OVM = 0 ppm
	3-4	SS-2 2"	1.0	—	3-4 ft: **SILTY CLAY (CL)**, brown, moist to dry, hard, caliche in vugs and as coatings in isolated subrounded sand	
5'	4-6	SS-3 3"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (CL)**, as logged 3-4 ft, with increasing caliche	OVM = 0 ppm
	6-8	SS-4 2"	2.0	—	6-8 ft: **SILTY ORGANIC CLAY (CL)**, as logged 3-6 ft, with increasing caliche and isolated sand with caliche coatings	OVM = 0 ppm
	8-10	SS-5 3"	2.0	—	8-10 ft: **SILTY ORGANIC CLAY (CL)**, as logged 3-8 ft, with decreasing caliche	OVM = 0 ppm
10'	10-12	SS-6 2"	2.0	—	10-12 ft: **SANDY SILT WITH CLAY (ML)**, light brown, dry, hard, isolated iron staining, black organics	OVM = 0 ppm
	12-14	SS-7 3"	1.3	—	12-14 ft: **SANDY SILT WITH CLAY (ML)**, as logged 10-12 ft, with limestone gravel to 2" from 12.5-13.0 ft bgs	OVM = 0 ppm
15'	14-16	SS-8 3"	2.0	—	14-16 ft: **SILTY CLAY (CL)**, brown, hard, dry to moist, iron stained vugs of black organics	OVM = 0 ppm
	16-18	SS-9 3"	2.0	—	16-18 ft: **SILTY CLAY (CL)**, as logged 14-16 ft, with <5% sand	OVM = 0 ppm
	18-20	SS-10 3"	2.0	—	18-20 ft: **SILTY CLAY (CL))**, as logged 14-18 ft	OVM = 0 ppm
20'	20-22	SS-11 2"	2.0	—	20-22 ft: **SILTY CLAY (CL)**, as logged 14-20 ft, with ~30% subangular sand 20-20.5 ft bgs	OVM = 0 ppm
	22-24	SS-12 3"	1.0	—	22-24 ft: **CLAYEY SAND (SC)**, light brown, moist to dry, hard, iron stained, subangular sand	OVM = 0 ppm
25'	24-26	SS-13 3"	0.7	—	24-26 ft: **CLAYEY SAND (SC)**, as logged 22-24 ft	OVM = 0 ppm Hard drilling
	26-28	SS-14 3"	0.2	—	26-28 ft: **CLAYEY SAND (SC)**, as logged 22-26 ft	OVM = 0 ppm Hard drilling
30'	28-30	SS-15 3"	0.1	—	28-30 ft: **CLAYEY SAND (SC)**, as logged 22-28 ft, loose sand below water table, putting catchers in the split spoons	OVM = 0 ppm Water Table at 28 ft bgs

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW334 MW12-4	2 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Marlow Between Nightengale and Ballard

ELEVATION N:566088.29 E:2141427.48 ELEV: 677.80 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 28 ft bgs START 11-16-98 FINISH 11-16-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'	30-32	SS-16 2"	1.3	—	30-32 ft: **CLAYEY SAND (SC)**, tan, wet, firm, subangular	OVM = 0 Water level rising inside augers
	32-33	SS-17 2"	2.0	—	32-33.5 ft: **CLAYEY SAND (SC)**, as logged 30-32 ft, wet	OVM = 0
	33-34	SS-18 2"	1.0	—	33.5-34.5 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained, gypsum crystals	OVM = 0 Navarro Clay
					Total Depth = 34.5 ft bgs **Setting Well at 34.5 ft bgs**	
35'						
40'						
45'						
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW335 MW12-5	1 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Andy North of Thompson

ELEVATION N:569137.50 E:2142087.51 ELEV:684.41 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 30 ft bgs START 11-17-98 FINISH 11-17-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-1	—	—	—	0-1 ft: **ASPHALT AND ROAD BASE (NACM)**	OVM = 0 ppm
	1-3	SS-1 3"	2.0	—	1-3 ft: **SILTY ORGANIC CLAY (OH)**, black, dry to moist, hard, sand size caliche throughout	OVM = 0 ppm
	3-4	SS-2 2"	1.0	—	3-4 ft: **SILTY ORGANIC CLAY (OH)**, as logged 1-3 ft	OVM = 0 ppm
5'	4-6	SS-3 3"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 1-4 ft	OVM = 0 ppm
	6-8	SS-4 2"	2.0	—	6-8 ft: **SILTY CLAY (CL)**, brown, dry, hard, isolated caliche coatings on sand, vugs filled with caliche, some iron staining	OVM = 0 ppm
	8-10	SS-5 3"	1.4	—	8-10 ft: **SILTY CLAY (CL)**, as logged 6-8 ft, with increasing sand and caliche content	OVM = 0 ppm
10'	10-12	SS-6 3"	2.0	—	10-12 ft: **SILTY CLAY (CL)**, as logged 6-10 ft	OVM = 0 ppm
	12-14	SS-7 2"	2.0	—	12-14 ft: **CLAYEY SILT (ML)**, brown, dry, hard, iron stained, vugs of caliche common, no sand	OVM = 0 ppm
15'	14-16	SS-8 2"	1.1	—	14-16 ft: **CLAYEY SILT (ML)**, as logged 12-14 ft	OVM = 0 ppm
	16-18	SS-9 2"	2.0	—	16-18 ft: **CLAYEY SILT (ML)**, as logged 12-16 ft	OVM = 0 ppm
	18-20	SS-10 2"	1.2	—	18-20 ft: **CLAYEY SILT (ML)**, as logged 12-18 ft, with isolated subrounded limestone sand	OVM = 0 ppm
20'	20-22	SS-11 2"	2.0	—	20-22 ft: **SILTY CLAY (CL)**, light brown, dry, firm to hard, vugs of caliche, iron stained, black organic material of parting surfaces	OVM = 0 ppm
	22-24	SS-12 2"	2.0	—	22-24 ft: **SILTY CLAY (CL)**, as logged 20-22 ft	OVM = 0 ppm
25'	24-26	SS-13 2"	2.0	—	24-26 ft: **SILTY CLAY (CL)**, as logged 20-24 ft	OVM = 0 ppm
	26-28	SS-14 2"	2.0	—	26-28 ft: **SILTY CLAY (CL)**, as logged 20-26 ft, with isolated sand	OVM = 0 ppm
30'	28-30	SS-15 2"	1.4	—	28-30 ft: **CLAYEY SAND (SC)**, light brown to gray, dry, hard, iron stained with black organics and isolated gravel from 28.5-29.0 ft	OVM = 0 ppm

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.20	SS050MW335 MW12-5	2 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Andy North of Thompson

ELEVATION N:569137.50 E:2142087.51 ELEV:684.41 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 30 ft bgs START 11-17-98 FINISH 11-17-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'	30-32	SS-16 3"	0.7	—	30-32 ft: **WELL GRADED GRAVEL (GP)**, light tan, hard, wet, limestone and chert gravel subangular to 2"	OVM = 0 Water table at 30 ft bgs Hard drilling, will drill through gravel and resume sampling
	32-34	—	—	—	32-34 ft: **WELL GRADED GRAVEL (GP)**, as logged 30-32 ft, logged from cuttings	OVM = 0 Rough drilling
	34-35	SS-17 3"	1.0	—	34-35 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained with black organics, gypsum crystals	OVM = 0 Navarro Clay
35'					**Total Depth = 35 ft bgs** **Setting Well at 35 ft bgs**	
40'						
45'						
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW336 MW12-6	1 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Darlington North of Meaefee

ELEVATION N:571118.13 E:2142434 ELEV:679.18 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 36 ft bgs START 11-18-98 FINISH 11-18-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-1	—	—	—	0-1 ft: **ASPHALT AND ROAD BASE (NACM)**	OVM = 0 ppm Drilled through asphalt and base 0-1 ft
	1-2	SS-1 3"	1.0	—	1-2 ft: **SILTY ORGANIC CLAY (OH)**, black, dry to moist, hard, sand size caliche throughout	OVM = 0 ppm
	2-4	SS-2 2"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, as logged 1-2 ft	OVM = 0 ppm
5'	4-6	SS-3 3"	1.8	—	4-6 ft: **CLAY WITH SAND (CL)**, brown, dry, hard, vugs with black organic material, isolated subrounded limestone sand with caliche coatings	OVM = 0 ppm
	6-8	SS-4 3"	2.0	—	6-8 ft: **SILTY CLAY (CL)**, light tan, dry, hard, isolated black organics	OVM = 0 ppm
	8-10	SS-5 2"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, as logged 6-8 ft	OVM = 0 ppm
10'	10-12	SS-6 3"	1.3	—	10-12 ft: **SILTY CLAY (CL)**, as logged 6-10 ft, isolated limestone sand from 10-10.5 ft with caliche coatings	OVM = 0 ppm
	12-14	SS-7 2"	1.1	—	12-14 ft: **SILTY CLAY (CL)**, as logged 6-12 ft	OVM = 0 ppm
15'	14-16	SS-8 2"	1.2	—	14-16 ft: **SILTY CLAY (CL)**, as logged 6-14 ft	OVM = 0 ppm
	16-18	SS-9 2"	1.4	—	16-18 ft: **CLAYEY SILT (ML)**, light brown, dry, hard, vugs with black organics and isolated caliche	OVM = 0 ppm
	18-20	SS-10 2"	1.3	—	18-20 ft: **CLAYEY SILT (ML)**, as logged 16-18 ft	OVM = 0 ppm
20'	20-22	SS-11 2"	1.8	—	20-22 ft: **SANDY SILT (ML)**, light brown, dry, hard, iron stained in isolated sections	OVM = 0 ppm
	22-24	SS-12 2"	1.5	—	22-24 ft: **SANDY SILT (ML)**, as logged 20-22 ft	OVM = 0 ppm
25'	24-26	SS-13 2"	2.0	—	24-26 ft: **SANDY SILT (ML)**, as logged 20-24 ft, with increasing clay, ~10% glauconitic sand	OVM = 0 ppm Rough drilling 24-24.5 ft
	26-28	SS-14 2"	0.9	—	26-28 ft: **SANDY SILT (ML)**, as logged 20-26 ft, with glauconitic sand	OVM = 0 ppm
30'	28-30	SS-15 2"	0.8	—	28-30 ft: **SANDY SILT (ML)**, as logged 20-28 ft	OVM = 0 ppm Steam coming out of augers OVM = 0/0/0 Top of Casing

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW336 MW12-6	2 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Darlington North of Menefee

ELEVATION N:571118.13 E:2142434.19 ELEV:679.18 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 36 ft bgs START 11-18-98 FINISH 11-18-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'	30-32	SS-16 3"	0.5	—	30-32 ft: **SANDY SILT (ML)**, as logged 20-30 ft	OVM = 0 Very hard, slow drilling
	32-34	SS-17 3"	0.5	—	32-34 ft: **SANDY SILT (ML))**, as logged 20-32 ft	OVM = 0
35'	34-36	SS-18 2"	0.3	—	34-36 ft: **CLAY WITH GRAVEL (CL)**, light tan, wet, hard, limestone and chert gravel to 1.5 ft	OVM = 0
	36-40	—	—	—	36-40 ft: **GRAVEL WITH CLAY (GC)**, light brown, wet, hard, limestone chert gravel subangular	Water table at 36 ft bgs, very hard OVM = 0/0/0 Very hard drilling in gravel, will drill through it and log from cuttings
40'	40-41	SS-19 2"	2.0	—	40-41 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained with black organics	OVM = 0 Navarro Clay
					Total Depth = 41 ft bgs **Setting Well at 41 ft bgs**	
45'						
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW337 MW12-7	1 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Jewel East of Cupples

ELEVATION N:566435.66 E:2143521 ELEV:673.71 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE Dry START 11-24-98 FINISH 11-24-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	—	—	—	0-2 ft: **ASPHALT AND ROAD BASE (NACM)**	OVM = 0 ppm Drilled out to 2 ft bgs
	2-4	SS-1 3"	2.0	—	2-4 ft: **SANDY CLAY WITH SILT (CL)**, brown, dry, hard, caliche coatings on sand	OVM = 0 ppm
5'	4-6	SS-2 2"	1.6	—	4-6 ft: **SANDY CLAY WITH SILT (CL)**, as logged 2-4 ft	OVM = 0 ppm
	6-8	SS-3 3"	2.0	—	6-8 ft: **SANDY CLAY WITH SILT (CL)**, as logged 2-6 ft	OVM = 0 ppm
	8-10	SS-4 2"	2.0	—	8-10 ft: **SANDY CLAY WITH SILT (CL)**, as logged 2-8 ft	OVM = 0 ppm
10'	10-12	SS-5 3"	2.0	—	10-12 ft: **SILTY CLAY (CL)**, brown, dry, stiff, vugs filled with caliche	OVM = 0 ppm
	12-14	SS-6 2"	1.4	—	12-14 ft: **SILTY CLAY (CL)**, as logged 10-12 ft	OVM = 0 ppm
15'	14-16	SS-7 3"	2.0	—	14-16 ft: **SILTY CLAY (CL)**, as logged 10-14 ft	OVM = 0 ppm
	16-18	SS-8 2"	2.0	—	16-18 ft: **SILTY CLAY (CL)**, as logged 10-16 ft	OVM = 0 ppm
	18-20	SS-9 3"	2.0	—	18-20 ft: **CLAYEY SILT (ML)**, brown, dry, hard, iron stained, vugs filled with caliche	OVM = 0 ppm
20'	20-22	SS-10 2"	2.0	—	20-22 ft: **CLAYEY SILT (ML)**, as logged 18-20 ft	OVM = 0 ppm
	22-24	SS-11 3"	1.0	—	22-24 ft: **CLAYEY SILT (ML)**, as logged 18-22, light brown, isolated sand 22.5-23.0 ft	OVM = 0 ppm
25'	24-26	SS-12 3"	0.9	—	24-26 ft: **CLAYEY SILT WITH SAND (ML)**, light gray, dry, hard, subrounded limestone and chert sand	OVM = 0 ppm
	26-28	SS-13 3"	0.8	—	26-28 ft: **CLAYEY SILT WITH SAND (ML)**, as logged 24-26 ft, with isolated limestone and chert gravel	OVM = 0 ppm
30'	28-30	SS-14 2"	0.3	—	28-30 ft: **GRAVEL WITH CLAY (GC)**, brown, moist, hard, limestone and chert gravel subangular to 1.5"	OVM = 0 ppm Rough drilling

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW337 MW12-7	2 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Jewel East of Cupples

ELEVATION N:566435.66 E:2143521.31 ELEV:673.71 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE Dry START 11-24-98 FINISH 11-24-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'	30-33	SS-15 3"	2.0	—	30-33 ft: **SILTY SAND WITH CLAY (SC)**, light gray, dry, hard, iron stained with isolated limestone gravel	OVM borehole = 0/0/0 Rough drilling Logging from drill cuttings
	33-35	—	—	—	33-35 ft: **SILTY SAND WITH CLAY (SC)**, as logged 30-33 ft, dry	OVM = 0 Rough drilling at 33 ft bgs
35'	35-38	—	—	—	35-38 ft: **SILTY SAND WITH CLAY (SC)**, as logged 30-35 ft	Hard drilling, no gravel Logged from cuttings
	38-39	SS-16 3"	1.0	—	38-39 ft: **SILTY CLAY (CL)**, olive gray, dry, hard, iron stained,gypsum crystals	OVM = 0 Navarro Clay
40'					**Total Depth = 39 ft bgs** **Setting Well at 39 ft bgs**	
45'						
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW338 MW12-8	1 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Kirk West of Cupples

ELEVATION N:569369.64 E:2143575.46 ELEV:675.31 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 24 ft bgs START 11-30-98 FINISH 11-30-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	—	—	—	0-2 ft: **ASPHALT AND ROAD BASE (NACM)**	OVM = 0/0/0 ppm
	2-4	SS-1 3"	2.0	—	2-4 ft: **SILTY CLAY (CL)**, brown, dry, hard, iron stained, vugs filled with caliche, isolated limestone sand with caliche coatings	OVM = 0 ppm
5'	4-6	SS-2 2"	2.0	—	4-6 ft: **SILTY CLAY (CL)**, as logged 2-4 ft	OVM = 0 ppm
	6-8	SS-3 3"	2.0	—	6-8 ft: **SILTY CLAY (CL)**, as logged 2-6 ft, sand not present	OVM = 0 ppm
	8-10	SS-4 2"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, as logged 2-8 ft, sand not present	OVM = 0 ppm
10'	10-12	SS-5 3"	2.0	—	10-12 ft: **SILT WITH SAND AND CLAY (ML)**, light brown, dry, hard, iron stained, isolated caliche, small amount of black organics	OVM = 0 ppm
	12-14	SS-6 3"	1.2	—	12-14 ft: **SILT WITH SAND AND CLAY (ML)**, as logged 10-12 ft	OVM = 0 ppm
15'	14-16	SS-7 3"	1.0	—	14-16 ft: **SILT WITH SAND AND CLAY (ML)**, as logged 10-14 ft	OVM = 0 ppm
	16-18	SS-8 3"	0.8	—	16-18 ft: **SAND WITH CLAY AND SILT (SC)**, light brown, dry to moist, firm, subangular, well sorted	OVM = 0 ppm
	18-20	SS-9 3"	0.7	—	18-20 ft: **SAND WITH CLAY AND SILT (SC)**, as logged 16-18 ft	OVM = 0 ppm
20'	20-22	SS-10 3"	0.7	—	20-22 ft: **SAND WITH CLAY AND SILT (SC)**, as logged 16-20 ft	OVM = 0 ppm
	22-24	SS-11 3"	0.5	—	22-24 ft: **SAND WITH CLAY AND SILT (SC)**, as logged 16-22, moist, increasing clay content	OVM = 0 ppm
25'	24-26	SS-12 3"	0.0	—	24-26 ft: **SAND WITH CLAY AND SILT (SC)**, as logged 16-24 ft, wet	OVM = 0 ppm Water Table at 24 ft bgs Smooth drilling, still in sand
	26-28	SS-13 2"	0.4	—	26-28 ft: **GRAVEL WITH CLAY AND SAND (GC)**, light brown, wet, hard, limestone and chert gravel to 1.5" subrounded	OVM = 0 ppm Rough drilling, will drill through gravels and log rest of boring from cuttings
	28-30	—	—	—	28-30 ft: **GRAVEL WITH CLAY AND SAND (GC)**, as logged 26-28 ft	OVM = 0 ppm Drilling air rotary at 28.5 ft
30'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW338 MW12-8	2 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Kirk West of Cupples

ELEVATION N:569369.64 E:2143575.46 ELEV:675.31 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 24 ft bgs START 11-30-98 FINISH 11-30-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'	30-32	—	—	—	30-32 ft: **GRAVEL WITH CLAY (GC)**, as logged 26-30 ft	OVM borehole = 0/0/0 Hollow stem auger drilling at 31.5 ft bgs
	32-33	SS-14 3"	1.0	—	32-33 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained	OVM borehole = 0 Navarro Clay
					Total Depth = 33 ft bgs **Setting Well at 33 ft bgs**	
35'						
40'						
45'						
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW339 MW12-9	1 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Menetee East of Cupples

ELEVATION N:570557.97 E:2144115.28 ELEV:675.16 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT 8-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE Dry START 12-2-98 FINISH 12-2-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	—	—	—	0-0.4 ft: **CONCRETE (NACM)** 0.4-2 ft: **ROAD BASE (NACM)**	OVM = 0/0/0 ppm Drilled through concrete sidewalk with concrete bit
	2-4	SS-1 3"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, black, moist, stiff to hard, roots and sand size caliche throughout	OVM = 0 ppm
5'	4-6	SS-2 2"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (CL)**, as logged 2-4 ft	OVM = 0 ppm
	6-8	SS-3 3"	2.0	—	6-8 ft: **SILTY CLAY (CL)**, brown, dry, hard, iron stained with vugs filled with caliche	OVM = 0 ppm
	8-10	SS-4 2"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, as logged 6-8 ft	OVM = 0 ppm
10'	10-12	SS-5 3"	2.0	—	10-12 ft: **CLAYEY SILT (ML)**, light brown, dry, hard, sparse black organics, vugs filled with caliche, isolated sand with caliche coatings	OVM = 0 ppm
	12-14	SS-6 2"	2.0	—	12-14 ft: **CLAYEY SILT (ML)**, as logged 10-12 ft	OVM = 0 ppm
15'	14-16	SS-7 3"	1.7	—	14-16 ft: **CLAYEY SILT (ML)**, as logged 10-14 ft	OVM = 0 ppm
	16-18	SS-8 2"	2.0	—	16-18 ft: **CLAYEY SILT (ML)**, as logged 10-16 ft, with sand	OVM = 0 ppm
	18-20	SS-9 2"	0.3	—	18-20 ft: **SAND WITH CLAY (SC)**, brown, dry, hard, caliche coatings on limestone sand, iron stained	OVM = 0 ppm
20'	20-22	SS-10 2"	0.3	—	20-22 ft: **SAND WITH CLAY (SC)**, as logged 18-20 ft, with isolated chert gravel to 0.5 ft	OVM = 0 ppm
	22-24	SS-11 2"	0.4	—	22-24 ft: **GRAVEL WITH CLAY (GC)**, brown, dry, hard, limestone and chert gravel to 1.5" subrounded	OVM = 0 ppm Rough drilling, will log from cuttings as gravel will cause little to no recovery in spoons
25'	24-30	—	—	—	24-30 ft: **GRAVEL WELL GRADED (GP)**, brown, dry, hard, limestone and chert gravel to 2" subrounded	OVM borehole = 0/0/0 Pull augers at 28 ft. and change cutter head on lead
30'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW339 MW12-9	2 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Menefee East of Cupples

ELEVATION N:570557.97 E:2144115.28 ELEV:675.16 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE Dry START 12-2-98 FINISH 12-2-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'	30-32	—	—	—	30-32 ft: **GRAVEL WELL GRADED (GP)**, as logged 24-30 ft	OVM borehole = 0/0/0
	32-35	SS-12 2"	2.0	—	32-35 ft: **SAND WITH CLAY (SC)**, light gray, moist, firm, iron stained, well sorted, isolated gravel with caliche coatings	OVM borehole = 0/0/0 2" spoon 32-34 ft Logged cuttings from 34-35 ft Smooth drilling with no pressure from Kelly on rig Possibly Navarro Transition Zone but not enough clay
35'		—	—	—		
	35-38	—	—	—	35-38 ft: **SAND WITH CLAY (SC)**, as logged 32-35 ft	OVM borehole = 0/0/0 Logged from cuttings Smooth drilling with no pressure from the Kelly on the rig
	38-39	SS-13 2"	1.0	—	38-39 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained with black organics on parting surfaces	OVM = 0 ppm Navarro Clay
40'					**Total Depth = 39 ft bgs** **Setting Well at 39 ft bgs**	
45'						
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW340 MW12-10	1 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Village South of Bedford

ELEVATION N:567558.55 E:2145001.34 ELEV:669.80 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 26 ft bgs START 12-11-98 FINISH 12-11-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION (SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY)	COMMENTS (DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION)
0'	0-2	—	—	—	0-2 ft: **ASPHALT AND ROAD BASE (NACM)**	OVM = 0/0/0 ppm
	2-4	SS-1 3"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, balck, dry, hard, sand size caliche	OVM = 0 ppm
5'	4-6	SS-2 2"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 2-4 ft	OVM = 0 ppm
	6-8	SS-3 3"	2.0	—	6-8 ft: **SILTY CLAY (CL)**, brown, dry, hard, vugs filled with caliche, isolated sand	OVM = 0 ppm
	8-10	SS-4 2"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, as logged 6-8 ft	OVM = 0 ppm
10'	10-12	SS-5 3"	1.3	—	10-12 ft: **SILTY CLAY (CL)**, as logged 6-10 ft	OVM = 0 ppm
	12-14	SS-6 2"	1.1	—	12-14 ft: **SILT WITH CLAY (ML)**, brown to light brown, dry, hard, iron stained, caliche in vugs	OVM = 0 ppm
15'	14-16	SS-7 2"	2.0	—	14-16 ft: **SILT WITH CLAY (ML)**, as logged 12-14 ft	OVM = 0 ppm
	16-18	SS-8 2"	1.7	—	16-18 ft: **SILT WITH CLAY (ML)**, as logged 12-16 ft	OVM = 0 ppm
	18-20	SS-9 2"	1.6	—	18-20 ft: **SILT WITH CLAY (ML)**, as logged 12-18 ft	OVM = 0 ppm
20'	20-22	SS-10 2"	1.6	—	20-22 ft: **SAND WITH CLAY (SC)**, gray, dry, firm, iron stained	OVM = 0 ppm
	22-24	SS-11 2"	1.8	—	22-24 ft: **SILT WITH CLAY (ML)**, light gray, dry, hard, iron stained.	OVM = 0 ppm
25'	24-26	SS-11 2"	1.7	—	24-26 ft: **SILT WITH CLAY (ML)**, as logged 22-24 ft, with isolated subrounded gravel to 0.5"	OVM = 0 ppm Water Table at 26 ft bgs
	26-28	SS-11 2"	1.6	—	26-28 ft: **SAND WITH CLAY AND SILT (SC)**, gray, wet, firm, iron stained, some sand glauconitic	OVM = 0 ppm
	28-30	SS-11 2"	0.8	—	28-30 ft: **SAND WITH CLAY AND SILT (SC)**, as logged 26-28 ft, wet	OVM = 0 ppm
30'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW340 MW12-10	2 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Village South of Bedford

ELEVATION N:567558.55 E:2145001.34 ELEV:669.80 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 26 ft bgs START 12-11-98 FINISH 12-11-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'	30-32	SS-15 2"	1.0	—	30-31 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained	OVM borehole = 0/0/0 Navarro Clay
					Total Depth = 31 ft bgs **Setting Well at 31 ft bgs**	
35'						
40'						
45'						
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW341 MW12-11	1 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Darby East of Cupples

ELEVATION N:569549.89 E:2146554.14 ELEV:663.51 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 24 ft bgs START 12-14-98 FINISH 12-15-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION (SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY)	COMMENTS (DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION)
0'	0-2	—	—	—	0-2 ft: **ASPHALT AND ROAD BASE (NACM)**	OVM = 0 ppm
	2-4	SS-1 3"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, black, dry, hard, sand size caliche	OVM = 0 ppm
5'	4-6	SS-2 2"	2.0	—	4-6 ft: **SILTY CLAY (CL)**, brown, dry, hard, vugs filled with caliche	OVM = 0 ppm
	6-8	SS-3 3"	2.0	—	6-8 ft: **SILTY CLAY (CL)**, as logged 4-6 ft	OVM = 0 ppm
10'	8-10	SS-4 2"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, as logged 4-8 ft	OVM = 0 ppm
	10-12	SS-5 3"	2.0	—	10-12 ft: **SILTY CLAY (CL)**, as logged 4-10 ft, gray to light gray with black organics	OVM = 0 ppm
	12-14	SS-6 2"	1.8	—	12-14 ft: **SILTY CLAY (CL)**, as logged 4-12 ft, light gray	OVM = 0 ppm
15'	14-16	SS-7 3"	1.0	—	14-16 ft: **SILTY CLAY (CL)**, as logged 4-14 ft, light gray	OVM = 0 ppm
	16-18	SS-8 3"	1.0	—	16-18 ft: **SILTY CLAY (CL)**, as logged 4-16 ft, light gray, isolated iron staining	OVM = 0 ppm
	18-20	SS-9 2"	2.0	—	18-20 ft: **SILT WITH CLAY (ML)**, light brown, hard, iron stained, black organics in vugs	OVM = 0 ppm
20'	20-22	SS-10 2"	2.0	—	20-22 ft: **SILTY ORGANIC CLAY (OH)**, as logged 18-20 ft, with isolated sand	OVM = 0 ppm
	22-24	SS-11 2"	0.7	—	22-24 ft: **SILT WITH SAND AND CLAY (ML)**, brown, dry, hard, caliche coatings on sand grains, iron stained	OVM = 0 ppm Rough drilling at 23 ft
25'	24-26	SS-11 2"	0.4	—	24-26 ft: **GRAVEL WITH SAND (GP)**, brown, wet, hard, limestone and chert gravel subrounded to 1"	OVM = 0 ppm Water table at 24 ft bgs Rough drilling, will drill through gravels and log from cuttings
	26-30	—	—	—	26-30 ft: **GRAVEL WITH SAND (GP)**, as logged 24-26 ft	Rough drilling 26-30 ft
30'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW341 MW12-11	2 OF 2

SOIL BORING LOG

PROJECT KELLY AFB ZONE 5 RI MOD 12 LOCATION Darby East of Cupples

ELEVATION N:569549.89 E:2146554.14 ELEV:663.14 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 24 ft bgs START 12-14-98 FINISH 12-15-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'	30-34	—	—	—	30-33 ft: **GRAVEL WITH SAND (GP)**, as logged 24-30 ft	OVM borehole = 0/0/0 Rough drilling
		SS-12 2"	1.0	—	33-34 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained	OVM = 0 Navarro Clay
					Total Depth = 34 ft bgs **Setting Well at 34 ft bgs**	
35'						
40'						
45'						
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW342 MW12-12	1 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Menefee North of Sonic Restaurant

ELEVATION N:570296.58 E:2140816.48 ELEV:685.52 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 33 ft bgs START 11-19-98 FINISH 11-19-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-1	—	—	—	0-1 ft: **CONCRETE AND ROAD BASE (NACM)**	OVM = 0 ppm Drilled through concrete sidewalk 0-0.5 ft
	1-3	SS-1 3"	2.0	—	1-3 ft: **SILTY ORGANIC CLAY (OH)**, black, moist, stiff, sand size caliche throughout	OVM = 0 ppm
	3-5	SS-2 2"	2.0	—	3-5 ft: **SILTY CLAY WITH SAND (CL)**, brown, moist to dry, hard, caliche coatings on isolated limestone sand	OVM = 0 ppm
5'	5-7	SS-3 3"	2.0	—	5-7 ft: **SILTY CLAY WITH SAND (CL)**, as logged 3-5 ft	OVM = 0 ppm
	7-8	SS-4 2"	1.0	—	7-8 ft: **SILTY CLAY WITH SAND (CL)**, as logged 3-7 ft	
	8-10	SS-5 3"	1.1	—	8-10 ft: **SILTY CLAY WITH SAND (CL)**, as logged 3-8 ft, lighter brown	OVM = 0 ppm
10'	10-12	SS-6 3"	1.3	—	10-12 ft: **CLAYEY SILT (ML)**, light brown, dry, hard, iron stained	OVM = 0 ppm
	12-14	SS-7 3"	1.2	—	12-14 ft: **CLAYEY SILT (ML)**, as logged 10-12 ft	OVM = 0 ppm
15'	14-16	SS-8 3"	1.0	—	14-16 ft: **CLAYEY SILT (ML)**, as logged 10-14 ft	OVM = 0 ppm
	16-18	SS-9 3"	1.0	—	16-18 ft: **CLAYEY SILT (ML)**, as logged 10-16 ft	OVM = 0 ppm
	18-20	SS-10 3"	0.6	—	18-20 ft: **CLAYEY SILT (ML)**, as logged 10-18 ft, with isolated vugs filled with caliche	OVM = 0 ppm
20'	20-22	SS-11 3"	0.5	—	20-22 ft: **CLAYEY SILT (ML)**, as logged 10-20 ft, with vugs filled with caliche	OVM = 0 ppm
	22-24	SS-12 3"	0.4	—	22-24 ft: **SILT WITH CLAY AND SAND (ML)**, dry, hard, single piece of rounded limestone gravel 2"	OVM = 0 ppm 1 piece of limestone gravel caused low recovery, rough drilling 23.5-24 ft bgs
25'	24-26	SS-13 3"	0.3	—	24-26 ft: **GRAVELLY CLAY (CL)**, brown, dry, hard, subangular limestone and chert gravel to 1"	OVM = 0 ppm
	26-28	SS-14 3"	0.6	—	26-28 ft: **GRAVELLY CLAY (CL)**, as logged 24-26 ft, with increasing sand content	OVM = 0 ppm Slow drilling, very hard
30'	28-30	SS-15 3"	0.5	—	28-30 ft: **GRAVEL WITH CLAY AND SAND (GC)**, brown, dry to moist, hard, subangular limestone and chert gravel to 1.5" and sand	OVM = 0 ppm Slow, hard drilling

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW342 MW12-12	2 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Menefee North of Sonic Restaurant

ELEVATION N:570296.58 E:2140816.48 ELEV:685.52 DRILLING CONTRACTOR

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 33 ft bgs START 11-19-98 FINISH 11-19-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS - DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'	30-35	—	—	—	30-35 ft: **GRAVEL WITH CLAY AND SAND (GC)**, as logged 28-30 ft	OVM borehole = 0/0/0 Drilling through gravel, will log from cuttings Water table at ~33 ft bgs Noted by steam coming from cuttings
35'	35-40	—	—	—	35-40 ft: **GRAVEL WITH CLAY AND SAND (GC)**, as logged 28-35 ft	OVM borehole = 0/0/0 Logged 35-40 ft from cuttings as we drilled through gravels, very rough drilling
40'	40-43	—	—	—	40-43 ft: **GRAVEL WITH CLAY AND SAND (GC)**, as logged 28-40 ft	OVM borehole = 0/0/0 Extremely hard drilling, very slow
	43-44	SS-16 2"	1.0	—	43-44 ft: **SILTY ORGANIC CLAY (CL)**, olive brown, dry	OVM= 0 Navarro Clay
45'					**Total Depth = 44 ft bgs** **Setting Well at 44 ft bgs**	
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS025MW343 MW12-13	1 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Wescott North of Menefee

ELEVATION N:571667.35 E:2138272.49 ELEV:693.64 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE Dry START 12-4-98 FINISH 12-4-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	—	—	—	0-2 ft: **ASPHALT AND BASE (NACM)**	OVM = 0 ppm Drilled through asphalt and road base
	2-4	SS-1 3"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, black, dry, hard, sand size caliche and roots throughout interval	OVM = 0 ppm
5'	4-6	SS-2 2"	2.0	—	4-6 ft: **SILTY CLAY WITH SAND (CL)**, brown, dry, hard, vugs with caliche sand with caliche coatings	OVM = 0 ppm
	6-8	SS-3 3"	1.8	—	6-8 ft: **SILTY CLAY WITH SAND (CL)**, as logged 4-6 ft, with iron stains	OVM = 0 ppm
	8-10	SS-4 2"	1.4	—	8-10 ft: **SILTY CLAY WITH SAND (CL)**, as logged 4-8 ft	OVM = 0 ppm
10'	10-12	SS-5 3"	0.6	—	10-12 ft: **SILTY CLAY WITH SAND (CL)**, as logged 4-10 ft, light brown	OVM = 0 ppm
	12-14	SS-6 3"	1.1	—	12-14 ft: **SILT WITH CLAY (ML)**, light tan, dry, hard, iron stains, black organics	OVM = 0 ppm
15'	14-16	SS-7 3"	1.3	—	14-16 ft: **SILT WITH CLAY (ML)**, as logged 12-14 ft, with sand	OVM = 0 ppm
	16-18	SS-8 2"	1.1	—	16-18 ft: **SILT WITH CLAY (ML)**, as logged 12-16 ft, with isolated sand	OVM = 0 ppm
	18-20	SS-9 2"	0.3	—	18-20 ft: **SILT WITH CLAY (ML)**, as logged 12-18 ft, with isolated gravel to 0.5"	OVM = 0 ppm
20'	20-22	SS-10 2"	0.2	—	20-22 ft: **GRAVEL WITH CLAY AND SILT (GC)**, brown, dry, hard, subrounded limestone and chert gravel	OVM = 0 ppm Drilling out through gravels
	22-25	—	—	—	22-25 ft: **GRAVEL WITH CLAY AND SILT (GC)**, as logged 20-22 ft	OVM borehole = 0/0/0 Logged from cuttings, rough drilling in gravels
25'	25-30	—	—	—	25-30 ft: **GRAVEL WELL GRADED (GP)**, brown, dry, hard, limestone and chert gravel to 2" subangular	OVM borehole = 0/0/0 Logged from cuttings because gravels will yield very little recovery in split spoons
30'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS025MW343 MW12-13	2 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Wescott North of Menefee

ELEVATION N:571667.35 E:2138272.49 ELEV:693.64 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE Dry START 12-4-98 FINISH 12-4-98 LOGGER B BRittain

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'	30-31.5	—	—	—	30-31.5 ft: **WELL GRADED GRAVEL (GP)**, as logged 25-30 ft bgs	OVM borehole = 0/0/0 Logged from cuttings, rough drilling
	31.5-32.5	SS-11 2"	1.5	—	31.5-32.5 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained with black organics	OVM = 0 Navarro Clay
					Total Depth = 32.5 ft bgs **Setting Well at 32.5 ft**	
35'						
40'						
45'						
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW344 MW12-14	1 OF 1

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Valencia by Highway 90

ELEVATION N:571703.02 E:2137013.76 ELEV:695.71 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE Dry START 11-23-98 FINISH 11-23-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	—	—	—	0-2 ft: **ASPHALT AND ROAD BASE (NACM)**	OVM = 0 ppm
	2-4	SS-1 3"	2.0	—	2-3 ft: **SILTY ORGANIC CLAY (OH)**, black, dry, hard, sand size caliche 3-4 ft: **SILTY CLAY WITH SAND (CL)**, brown, dry, hard, vugs filled with caliche and caliche as coatings in sand	OVM = 0 ppm
5'	4-6	SS-2 2"	2.0	—	4-6 ft: **SILTY CLAY WITH SAND (CL)**, as logged 3-4 ft	OVM = 0 ppm
	6-8	SS-3 3"	2.0	—	6-8 ft: **SILTY CLAY WITH SAND (CL)**, as logged 3-6 ft, with iron stains	OVM = 0 ppm
	8-10	SS-4 2"	2.0	—	8-10 ft: **SILTY CLAY WITH SAND (CL)**, as logged 3-8 ft	OVM = 0 ppm
10'	10-12	SS-5 3"	2.0	—	10-12 ft: **SILTY CLAY WITH SAND (CL)**, as logged 3-10 ft, with black organics in vugs	OVM = 0 ppm
	12-14	SS-6 2"	2.0	—	12-14 ft: **SILTY CLAY WITH SAND (CL)**, as logged 3-12 ft, with black organics	OVM = 0 ppm
15'	14-16	SS-7 3"	2.0	—	14-16 ft: **CLAYEY SILT (ML)**, light tan, dry, hard, vugs of black organics, iron stained	OVM = 0 ppm
	16-18	SS-8 2"	2.0	—	16-18 ft: **CLAYEY SILT (ML)**, as logged 14-16 ft, with well sorted sand 17.8-18 ft bgs	OVM = 0 ppm
	18-20	SS-9 3"	1.1	—	18-20 ft: **CLAYEY SILT (ML)**, as logged 16-18 ft	OVM = 0 ppm
20'	20-22	SS-10 3"	0.6	—	20-22 ft: **CLAYEY SILT (ML)**, as logged 16-20 ft	OVM = 0 ppm
	22-24	SS-11 3"	0.5	—	22-24 ft: **CLAYEY SILT (ML)** light brown, dry, hard, isolated limestone gravel to 1.5" subrounded	OVM = 0 ppm Gravel caused low recovery
25'	24-26	SS-12 2"	0.3	—	24-26 ft: **CLAYEY SILT (ML)**, as logged 22-24 ft, with increasing gravel content	OVM = 0 ppm Rough drilling
	26-28	SS-13 2"	0.3	—	26-28 ft: **CLAYEY GRAVEL WITH SAND (GC)**, brown, dry, very hard, subangular limestone and chert gravel to 1.5"	OVM = 0 ppm
	28-29	SS-14 2"	1.0	—	28-29 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained	OVM = 0 ppm Navarro Clay
30'					**Total Depth = 29 ft bgs** **Setting Well at 29 ft bgs**	

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW345 MW12-15	1 OF 1

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Guanajuato North of Highway 90

ELEVATION N:572085.54 E:2140429.79 ELEV:685.99 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE Dry START 12-7-98 FINISH 12-7-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	—	—	—	0-2 ft: **ASPHALT AND ROAD BASE (NACM)**	OVM = 0 ppm Drilled through asphalt and base
	2-4	SS-1 3"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, black, dry, hard, sand size caliche and roots throughout	OVM = 0 ppm
5'	4-6	SS-2 2"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 2-4 ft	OVM = 0 ppm
	6-8	SS-3 3"	2.0	—	6-8 ft: **SILTY CLAY (CL)**, brown, dry, hard, vugs of caliche, isolated limestone sand with caliche coatings	OVM = 0 ppm
	8-10	SS-4 2"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, as logged 6-8 ft	OVM = 0 ppm
10'	10-12	SS-5 3"	2.0	—	10-12 ft: **SANDY SILT (ML)**, brown, dry, firm to hard, caliche in vugs	OVM = 0 ppm
	12-14	SS-6 2"	2.0	—	12-14 ft: **SANDY SILT (ML)**, as logged 10-12 ft	OVM = 0 ppm
15'	14-16	SS-7 3"	2.0	—	14-16 ft: **SAND WITH CLAY (SC)**, light brown, dry, firm, iron staining, black organics	OVM = 0 ppm
	16-18	SS-8 2"	2.0	—	16-18 ft: **SAND WITH CLAY (SC)**, as logged 14-16 ft	OVM = 0 ppm
	18-20	SS-9 3"	1.1	—	18-20 ft: **SAND WITH CLAY (SC)**, as logged 14-18 ft, with gravel 19.5-19.8 to 0.5"	OVM = 0 ppm
20'	20-22	SS-10 3"	0.7	—	20-22 ft: **SAND WITH CLAY (SC)**, as logged 14-20 ft, with isolated gravel to 2.5" in cuttings	OVM = 0 ppm Very rough drilling
	22-24	SS-11 3"	1.0	—	22-23 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained	OVM = 0 ppm Navarro Clay
25'					**Total Depth = 23 ft bgs** **Setting Well at 23 ft bgs**	
30'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW468 MW12-1	1 OF 1

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION West of Fuels Mgt.

ELEVATION N:569356.97 E:2134925.54 ELEV:696.86 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 28 ft bgs START 12-7-98 FINISH 12-7-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	—	—	—	0-2 ft: **CONCRETE (NACM)**	OVM = 0/0/0
	2-4	SS-1 3"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, black, dry, hard, sand size caliche throughout	OVM = 0 ppm 1220 collect SIA042 for VOCs and metals from 2-4 ft
5'	4-6	SS-2 2"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 2-4 ft	OVM = 9 ppm
	6-8	SS-3 3"	2.0	—	6-8 ft: **SILTY ORGANIC CLAY (OH)**, as logged 2-6 ft	OVM = 0 ppm
	8-10	SS-4 2"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, brown, dry, hard, vugs filled with caliche, isolated sand with caliche coatings	OVM = 0 ppm
10'	10-12	SS-5 3"	2.0	—	10-12 ft: **SANDY SILT (CL)**, as logged 8-10 ft	OVM = 0 ppm
	12-14	SS-6 2"	2.0	—	12-14 ft: **SANDY SILT (CL)**, as logged 8-12 ft	OVM = 0 ppm
15'	14-16	SS-7 3"	2.0	—	14-16 ft: **SILT WITH CLAY (ML)**, brown, dry, hard, isolated sand, black organic material	OVM = 0 ppm
	16-18	SS-8 2"	2.0	—	16-18 ft: **SAND WITH CLAY AND SILT (SC)**, brown, dry, firm	OVM = 0 ppm
	18-20	SS-9 3"	2.0	—	18-20 ft: **SAND WITH CLAY AND SILT (SC)**, as logged 16-18 ft	OVM = 0 ppm
20'	20-22	SS-10 2"	2.0	—	20-22 ft: **SAND WITH CLAY AND SILT (SC)**, as logged 16-20 ft	OVM = 0 ppm
	22-24	SS-11 3"	1.1	—	22-23 ft: **SAND WITH CLAY AND SILT (SC)**, as logged 16-22 ft, moist 23-24 ft: **GRAVEL WITH CLAY AND SAND (GC)**, brown, moist, hard, limestone and chert sand to 1" subrounded	OVM = 0 ppm
25'	24-26	SS-12 2"	1.0	—	24-26 ft: **GRAVEL WITH CLAY AND SAND (GC)**, as logged 23-24 ft	OVM = 0 ppm
	26-28	SS-13 2"	1.1	—	26-28 ft: **GRAVEL WITH CLAY AND SAND (GC)**, as logged 23-26 ft	OVM = 0 ppm 1335 collect SIA043 for VOCs and metals from 26-28 ft
	28-30	SS-14 2"	2.0	—	28-28.5 ft: **GRAVEL WITH CLAY AND SAND (GC)**, as logged 23-28 ft 28.5-30 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained	OVM = 0 ppm Water table at 28 ft bgs Navarro Clay at 28.5 ft
30'						

Total Depth = 30 ft bgs Setting Well at 29.5 ft bgs

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW469 MW12-2	1 OF 1

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Southwest of Building 1414

ELEVATION N:569162.43 E:2135052.83 ELEV:694.52 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 24 ft bgs START 11-20-98 FINISH 11-20-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	SS-1 3"	2.0		0-2 ft: **SILTY ORGANIC CLAY (OH)**, black, moist, hard, roots and sand size caliche throughout	OVM =
	2-4	SS-2 2"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-2 ft	OVM = 0 ppm
5'	4-6	SS-3 3"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-4 ft	OVM = 9 ppm 0745 collect SIA025 and SIA026FD1 (dup) for VOCs and metals from 6-8 ft
	6-8	SS-4 2"	2.0	—	6-8 ft: **SILTY CLAY (CL)**, brown, dry, hard, iron stained, isolated sand, vugs filled with caliche	OVM = 0 ppm
	8-10	SS-5 3"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, as logged 6-8 ft	OVM = 0 ppm
10'	10-12	SS-6 2"	2.0	—	10-12 ft: **SANDY SILT (CL)**, as logged 6-10 ft	OVM = 0 ppm
	12-14	SS-7 3"	2.0	—	12-14 ft: **CLAYEY SAND WITH SILT (SC)**, reddish brown, dry, hard, subrounded sand, iron stained, isolated subrounded limestone gravel 13-13.5 ft	OVM = 0 ppm
15'	14-16	SS-8 2"	2.0	—	14-16 ft: **CLAYEY SAND WITH SILT (SC)**, as logged 12-14 ft, sand percentage decreased slightly	OVM = 0 ppm
	16-18	SS-9 3"	2.0	—	16-18 ft: **CLAYEY SAND WITH SILT (SC)**, as logged 12-16 ft, with gravel 17-17.5 ft	OVM = 0 ppm
	18-20	SS-10 3"	0.4	—	18-20 ft: **SILTY CLAY WITH GRAVEL (CL)**, greenish brown, dry, hard, isolated limestone gravel to 1.5" subrounded	OVM = 0 ppm Gravel caused low recovery Rough drilling at 19 ft bgs
20'	20-22	SS-11 2"	0.3	—	20-22 ft: **SAND WITH CLAY AND GRAVEL (SC)**, brown, hard, dry to moist, subrounded limestone and chert sand and gravel	OVM = 0 ppm Hard drilling
	22-24	SS-12 2"	0.3	—	22-24 ft: **SAND WITH CLAY AND GRAVEL (SC)**, as logged 20-22 ft	OVM = 0 ppm 0900 collect SIA027 for VOCs and metals from 22-24 ft
25'	24-26	SS-13 2"	0.4	—	24-26 ft: **GRAVEL WELL GRADED (GP)**, wet, hard, limestone and chert gravel to 2" subangular	OVM = 0 ppm Water table at 24 ft bgs
	26-28	SS-14 3"	1.5	—	26-26.5 ft: **GRAVEL WELL GRADED (GP)**, as logged 24-26 ft 26.5-27.5 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained, Navarro Clay	OVM = 0 ppm
30'					**Total Depth = 27.5 ft bgs** **Setting Well at 27.5 ft bgs**	

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW470 MW12-3	1 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Southeast of Building 1414

ELEVATION N:569173.15 E:2135230.59 ELEV:695.56 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 22 ft bgs START 11-16-98 FINISH 11-16-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	SS-1 3"	2.0	—	0-2 ft: **SILTY ORGANIC CLAY (OH)**, black, moist, hard,sand size caliche and roots throughout	OVM = 0 ppm
	2-4	SS-2 2"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-2 ft	OVM = 0 ppm
5'	4-6	SS-3 3"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-4 ft	OVM = 0 ppm
	6-8	SS-4 2"	2.0	—	6-8 ft: **SILTY CLAY (CL)**, brown, dry, hard, with ~5% caliche coated sand, isolated black organics	OVM = 0 ppm 1355 Collect SIA010 from 6-8 ft for VOCs, and metals
	8-10	SS-5 3"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, as logged 6-8 ft	OVM = 0 ppm
10'	10-12	SS-6 2"	2.0	—	10-12 ft: **SILTY CLAY (CL)**, as logged 6-10 ft	OVM = 0 ppm
	12-14	SS-7 3"	2.0	—	12-14 ft: **SILTY CLAY (CL)**, as logged 6-12 ft	OVM = 0 ppm
15'	14-16	SS-8 2"	1.1	—	14-16 ft: **SILTY CLAY (CL)**, as logged 6-14 ft	OVM = 0 ppm Rough drilling at 16 ft
	16-18	SS-9 3"	1.0	—	16-18 ft: **GRAVEL WITH CLAY AND SAND (GC)**, dry, hard, subrounded limestone and chert gravel to 2.5 ft	OVM = 0 ppm Hard drilling
	18-20	SS-10 2"	1.0	—	18-20 ft: **GRAVEL WITH CLAY AND SAND (GC)**, as logged 16-18 ft	OVM = 0 ppm Hard drilling
20'	20-22	SS-11 3"	0.4	—	20-22 ft: **GRAVEL WITH CLAY AND SAND (GC)**, as logged 16-20 ft	OVM = 0 ppm 1545 Collect SIA007 from 20-22 ft for VOCs and metals
	22-24	SS-12 3"	0.3	—	22-24 ft: **GRAVEL WELL GRADED (GP)**, light tan, wet, hard, subangular well graded limestone and chert gravel	OVM = 0 ppm Water table at 22 ft Will drill through gravel to Navarro because are below the water table and no more samples for analysis are to be collected, will log remainder of hole from cuttings
25'	24-30	—	—	—	24-30 ft: **GRAVEL WELL GRADED (GP)**, as logged 20-24 ft, logged from cutting and vibration of rig while drilling	Rough drilling 24-30 ft bgs
30'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW470 MW12-3	2 OF 2

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Southeast of Building 1414

ELEVATION N:569173.15 E:2135230.59 ELEV:695.56 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 22 ft bgs START 11-16-98 FINISH 11-16-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30'	30-31	SS-13 3"	1.0	—	30-31 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained with vugs of black organics	OVM = 0 Navarro Clay
					Total Depth = 31 ft bgs **Setting Well at 31 ft bgs**	
35'						
40'						
45'						
50'						
55'						
60'						

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW471 (MW12-18)	1 OF 1

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION By Yield Sign South of Building 1414

ELEVATION N:569191.72 E:2135433.63 ELEV:694.48 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 26 ft bgs START 11-17-98 FINISH 11-17-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-2	SS-1 3"	2.0		0-2 ft: **SILTY ORGANIC CLAY (OH)**, black, moist, hard, roots and sand size caliche throughout	OVM =
	2-4	SS-2 2"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-2 ft	OVM = 0 ppm
5'	4-6	SS-3 3"	2.0	—	4-6 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-4 ft	OVM = 0 ppm
	6-8	SS-4 2"	2.0	—	6-8 ft: **SILTY CLAY (CL)**, light brown, dry, hard, iron stained, caliche in vugs	OVM = 0 ppm 1410 collect SIA013 for VOCs and metals from 6-8 ft
	8-10	SS-5 3"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, as logged 6-8 ft	OVM = 0 ppm
10'	10-12	SS-6 2"	2.0	—	10-12 ft: **SANDY SILT (CL)**, as logged 6-10 ft	OVM = 0 ppm
	12-14	SS-7 3"	2.0	—	12-14 ft: **SANDY SILT (CL)**, as logged 6-12 ft, with isolated chert gravel to 1.5"	OVM = 0 ppm
15'	14-16	SS-8 2"	1.3	—	14-16 ft: **SANDY SILT (CL)**, as logged 6-14 ft, with isolated gravel to 1"	OVM = 0 ppm
	16-18	SS-9 3"	2.0	—	16-18 ft: **CLAYEY SILT (ML)**, light brown, dry, hard, isolated limestone and chert sand and gravel (~5%)	OVM = 0.ppm
	18-20	SS-10 2"	2.0	—	18-19 ft: **CLAYEY SILT (ML)**, as logged 16-18 ft 19-20 ft: **GRAVEL WITH SAND AND CLAY (GC)**, light brown, dry, hard, limestone and chert gravel to 1.5" subangular	OVM = 0 ppm
20'	20-22	SS-11 3"	no recovery	—	20-22 ft: **GRAVEL WITH SAND AND CLAY (GC)**, as logged 19-20 ft	OVM = 0 ppm Hard drilling Logged by way rig was drilling Gravel caused no recovery
	22-24	SS-12 3"	1.7	—	22-24 ft: **SILTY CLAY WITH GRAVEL (CL)**, light gray, dry, hard, limestone and chert gravel subrounded to 1.5"	OVM = 0 ppm
25'	24-26	SS-13 3"	2.0	—	24-26 ft: **SILTY CLAY WITH GRAVEL (CL)**, as logged 22-24	OVM = 0 ppm Very hard drilling, must be back in gravel 1615 collect SIA017 for VOCs and metals from 24-26 ft
	26-28	SS-14 3"	2.0	—	26-27 ft: **SILTY CLAY WITH GRAVEL (CL)**, as logged 22-26 ft, wet 27-28 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained with black organics	OVM = 0 ppm Water table at 26 ft bgs OVM = 0 ppm
30'					**Total Depth = 28 ft bgs** **Setting Well at 28 ft bgs**	

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW472 (MW12-16)	1 OF 1

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Outside Base Ops by Tree

ELEVATION N:563715.56 E:2135893.84 ELEV:679.11 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 20 ft bgs START 11-13-98 FINISH 11-13-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION (SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY)	COMMENTS (DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION)
0'	0-2	SS-1 3"	2.0		0-2 ft: **SILTY ORGANIC CLAY (OH)**, black, dry to moist, hard, sand size caliche and roots	OVM =
	2-4	SS-2 2"	2.0	—	2-4 ft: **SILTY ORGANIC CLAY (OH)**, as logged 0-2 ft	OVM = 0 ppm
5'	4-6	SS-3 3"	2.0	—	4-6 ft: **SILTY CLAY WITH SAND (CL)**, brown, dry to moist, hard, isolated limestone sand with caliche coating, caliche in vugs	OVM = 9 ppm
	6-8	SS-4 2"	2.0	—	6-8 ft: **SILTY CLAY WITH SAND (CL)**, as logged 4-6 ft	OVM = 0 ppm
	8-10	SS-5 3"	2.0	—	8-10 ft: **CLAYEY SILT WITH SAND (ML)**, brown, dry, hard, isolated limestone gravel and black organics	OVM = 0 ppm
10'	10-12	SS-6 2"	1.1	—	10-12 ft: **CLAYEY SILT WITH SAND (ML)**, as logged 8-10 ft	OVM = 0 ppm
	12-14	SS-7 3"	2.0	—	12-13 ft: **CLAYEY SILT WITH SAND (ML)**, as logged 8-12 ft 13-14 ft: **SILTY SAND WITH CLAY (SC-SL)**, brown, firm, dry, isolated caliche	OVM = 0 ppm
15'	14-16	SS-8 2"	2.0	—	14-16 ft: **SILTY SAND WITH CLAY (SC-SL)**, as logged 13-14 ft	OVM = 0 ppm
	16-18	SS-9 3"	1.4	—	16-18 ft: **CLAY WITH SILT AND SAND (CL)**, light brown, dry, hard, iron stained, isolated caliche	OVM = 0 ppm
	18-20	SS-10 3"	0.5	—	18-20 ft: **CLAY WITH GRAVEL AND SILT (CL)**, light brown, moist, hard, subrounded limestone and chert gravel	OVM = 0 ppm 1345 collect SIA004 for VOCs and metals from 18-20 ft
20'	20-22	SS-11 3"	1.0	—	20-22 ft: **GRAVEL WITH SAND (GP)**, light tan, wet, hard, limestone and chert gravel to 1.5", subangular	OVM = 0 ppm Water table at 20 ft bgs Will drill down to top of Navarro and drive spoon, remainder of log will be completed from cuttings
	22-25.5	—	—	—	22-25.5 ft: **GRAVEL WITH SAND (GP)**, as logged 20-22 ft	Rough drilling at 25 ft, still mostly gravel in cuttings
25'	26-28.5	SS-10 3" SS-11 2"	3.0	—	25.5-28.5 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained, black organics	Smooth drilling at 25.5 ft Split spoon confirms Navarro at 2' Setting well at 26.5 ft
30'					**Total Depth = 28.5 ft bgs** **Setting Well at 26.5 ft bgs**	

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET
111494.B1.30	SS050MW473 MW12-17	1 OF 1

SOIL BORING LOG

PROJECT Kelly AFB Zone 5 RI Mod 12 LOCATION Across Street from Base Ops by Yield Sign

ELEVATION N:563813.19 E:2135926.87 ELEV:679.18 DRILLING CONTRACTOR JEDI

DRILLING METHOD AND EQUIPMENT B-61 Mobile Drill with 8 1/4" OD HSA

WATER LEVEL AND DATE 20 ft bgs START 11-13-98 FINISH 11-13-98 LOGGER B. Rahe

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'	0-1	—	—	—	0-1 ft: **ASPHALT AND ROAD BASE (NACM)**	OVM = 0 ppm
	1-4	SS-1 3" SS-2 2"	3.0	—	1-4 ft: **SILTY ORGANIC CLAY (OH)**, black, dry, hard, sand size caliche throughout, isolated gravel	OVM = 0 ppm 0755 collect SIA005 for VOCs and metals from 1-3 ft Drove additional spoon 3-4 ft
5'	4-6	SS-4 3"	2.0	—	4-6 ft: **SILTY CLAY (CL)**, brown, dry, hard, iron stained, vugs of caliche, <5% chert gravel to 1", subangular	OVM = 0 ppm
	6-8	SS-5 2"	2.0	—	6-8 ft: **SILTY CLAY (CL)**, as logged 4-6 ft, with isolated sand	OVM = 0 ppm
	8-10	SS-6 3"	2.0	—	8-10 ft: **SILTY CLAY (CL)**, as logged 4-8 ft	OVM = 0 ppm
10'	10-12	SS-7 2"	1.1	—	10-12 ft: **GRAVEL WITH CLAY (GC)**, brown, dry, hard, subrounded limestone and chert gravel to 1" with black organics as coatings	OVM = 0 ppm
	12-14	SS-8 3"	1.2	—	12-14 ft: **CLAY WITH SILT AND SAND (CL)**, brown, dry, hard, isolated caliche, black organics in vugs, iron stained	OVM = 0 ppm
15'	14-16	SS-9 2"	1.0	—	14-16 ft: **GRAVEL WITH CLAY AND SAND (GC)**, brown, dry, hard, limestone and chert gravel to 2" subangular to angular	OVM = 0 ppm
	16-18	SS-10 3"	0.4	—	16-18 ft: **GRAVEL WITH CLAY AND SAND (GC)**, as logged 14-16 ft	OVM = 0 ppm
	18-20	SS-11 3"	0.4	—	18-20 ft: **GRAVEL WITH CLAY AND SAND (GC)**, as logged14-18 ft	OVM = 0 ppm 0845 collect SIA006 for VOCs and metals from 18-20 ft
20'	20-25.5	—	—	—	20-25.5 ft: **GRAVEL WITH SAND AND CLAY (GP)**, brown, wet, hard, limestone and chert gravel subrounded to 2"	OVM = 0/0/0 Water table at 20 ft bgs Rough drilling Drilled through gravel because are below water table and are not collecting any more samples for chemical analysis, will log remainder of hole from cuttings
25'	26-28.5	SS-12 3" SS-13 2"	3.0	—	25.5-28.5 ft: **SILTY CLAY (CL)**, olive brown, dry, hard, iron stained, black organics	OVM = 0/0/0 Driller hits Navarro at 25.5 ft Drive spoons 25.5 to 28.5 ft bgs to confirm
30'					**Total Depth = 28.5 ft bgs** **Setting Well at 26.5 ft bgs**	

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation Kelly Air Force Base

Site Marlow Street Between Ballard and Nightengale

Project Number 111494.B1.30

Drilling Contractor JEDI

Field Hydrogeologist B. Rahe

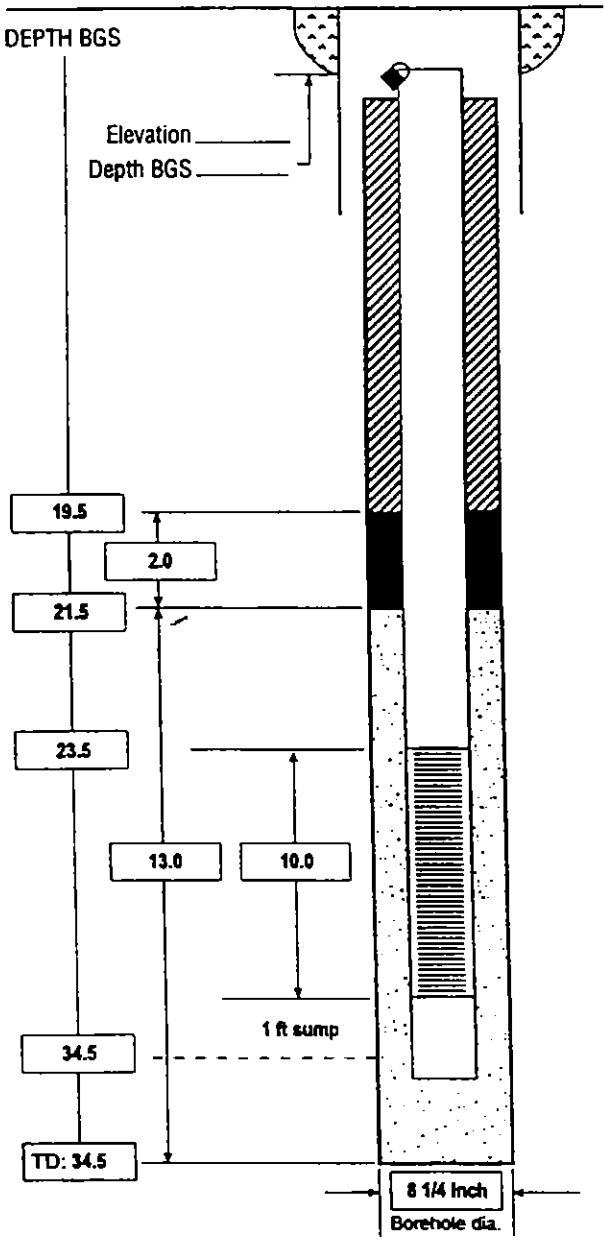
Well Number SS050MW334 (MW12-4)

Client/Project Zone 5 RI Mod 12

Starting date 11/16/98 time

Completion date 11/16/98 time

Well Coordinates 677,41



RISER PIPE
Type PVC and Stainless Steel
Diameter 2 Inch
Total Length (TOC to TOS) 0-23.5 ft

GROUT
Composition & Proportions
Tremied (Y / N)
Interval BGS

CENTRALIZERS (Y /(N))
Depth(s) BGS

SEAL
Type Medium Bentonite Chips
Source Pure Gold (50 lbs)

FILTER PACK
Type Silica Sand 21.5-34.5 ft
Amount Used 450 lbs
Tremied (Y /(N))
Source UNIMIN
Gr. Size Dist. 20-40

SCREEN
Type Stainless Steel Wrapped
Diameter 2 Inch
Slot Size & Type 0.010 Inch
Interval BGS 23.5-33.5 ft

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation: Kelly Air Force Base

Site: Andy North of Thompson

Project Number: 111494.B1.30

Drilling Contractor: JEDI

Field Hydrogeologist: B. Rahe

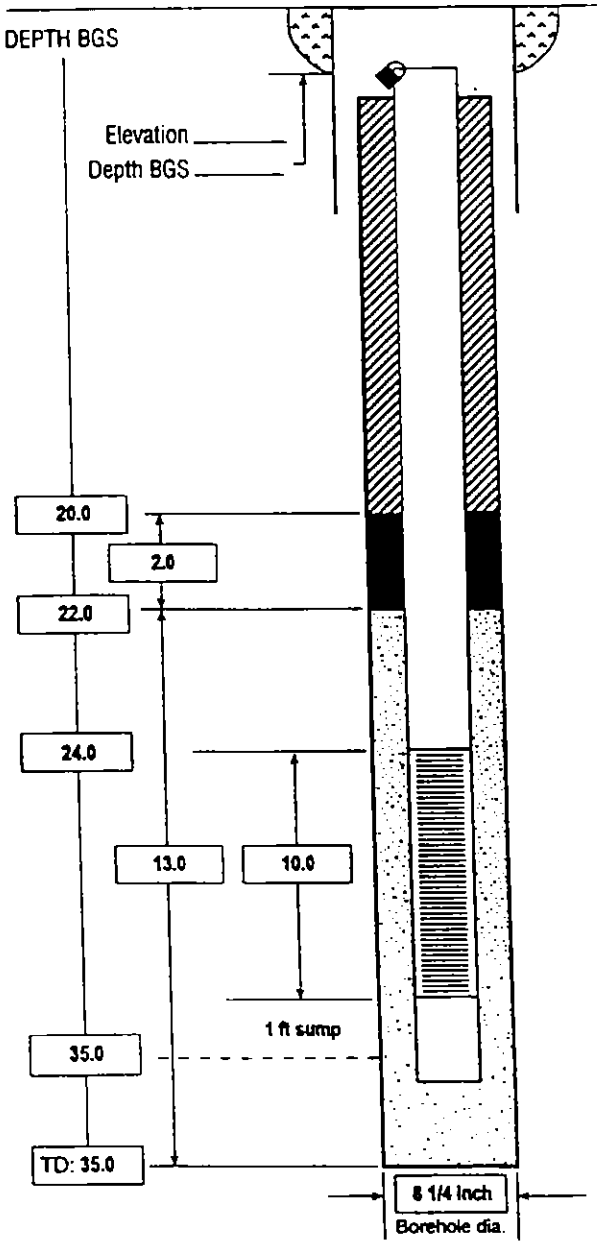
Well Number: SS050MW335 (MW12-5)

Client/Project: Zone 5 RI Mod 12

Starting: date 11/17/98 time

Completion: date 11/17/98 time

Well Coordinates: 684.06



RISER PIPE
Type: PVC and Stainless Steel
Diameter: 2 Inch
Total Length (TOC to TOS): 0-24 ft

GROUT
Composition & Proportions:
Tremied (Y / N)
Interval BGS:

CENTRALIZERS (Y / N)
Depth(s) BGS:

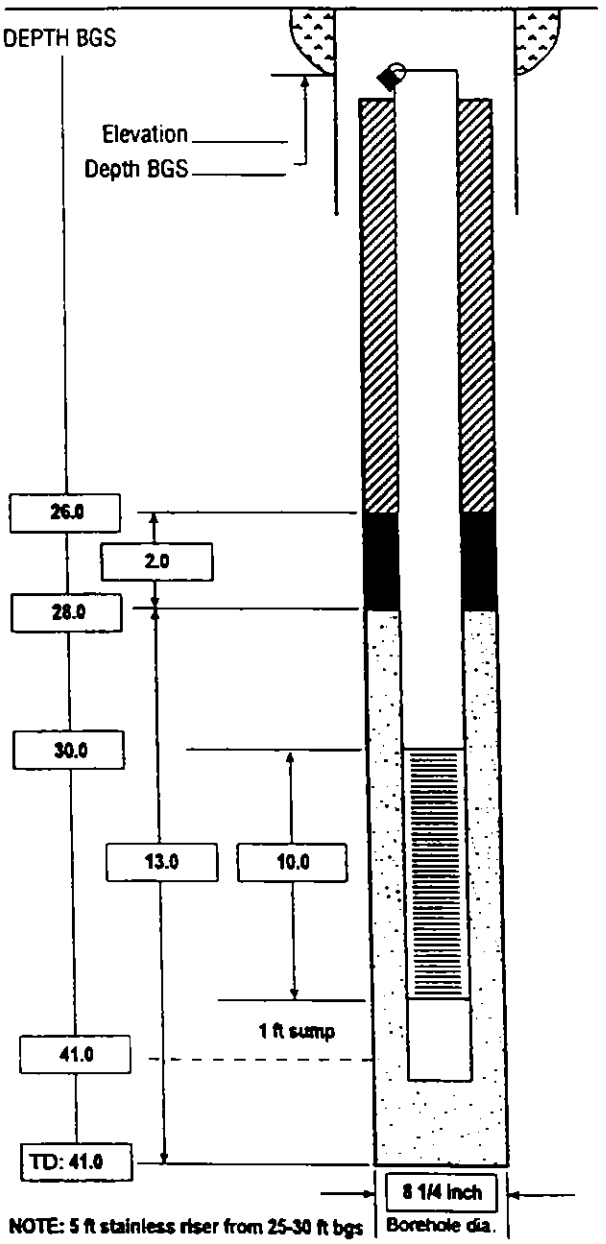
SEAL
Type: Medium Bentonite Chips
Source: Pure Gold (50 lbs)

FILTER PACK
Type: Silica Sand 22-35 ft
Amount Used: 450 lbs
Tremied (Y / N)
Source: Unimin
Gr. Size Dist.: 20-40

SCREEN
Type: Stainless Steel Wrapped
Diameter: 2 Inch
Slot Size & Type: 0.010 Inch
Interval BGS: 24-34 ft

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation: Kelly Air Force Base
Well Number: SS050MW336 (MW12-6)
Site: Darlington North of Menefee
Client/Project: Zone 5 RI Mod 12
Project Number: 111494.B1.30
Starting: date 11/18/98 time
Drilling Contractor: JEDI
Completion: date 11/18/98 time
Field Hydrogeologist: B. Rahe
Well Coordinates: 678, 84



RISER PIPE
Type: PVC and Stainless Steel
Diameter: 2 inch
Total Length (TOC to TOS): 0-30 ft (25-30 ft stainless)

GROUT
Composition & Proportions:
Tremied (Y / N)
Interval BGS:

CENTRALIZERS (Y / N)
Depth(s) BGS:

SEAL
Type: Medium Bentonite Chips
Source: Pure Gold

FILTER PACK
Type: Silica Sand
Amount Used: 450 lbs
Tremied (Y / N)
Source: UNIMIN
Gr. Size Dist.: 20-40

SCREEN
Type: Stainless Steel Wrapped
Diameter: 2 inch
Slot Size & Type: 0.010 inch
Interval BGS: 30-40 ft

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation Kelly Air Force Base

Well Number SS050MW337 (MW12-7)

Site Jewel East of Cupples

Client/Project Zone 5 RI Mod 12

Project Number 111494.B1.30

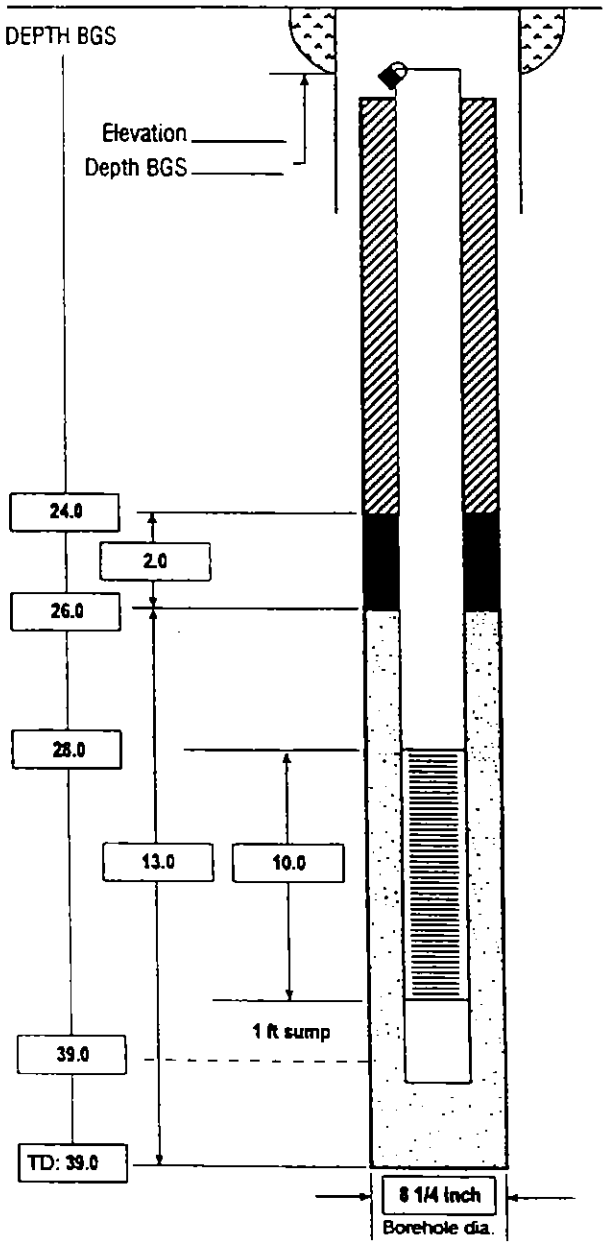
Starting date 11/24/98 time

Drilling Contractor JEDI

Completion date 11/24/98 time

Field Hydrogeologist B. Rahe

Well Coordinates 673.37



RISER PIPE
Type PVC
Diameter 2 inch
Total Length (TOC to TOS) 0-28 ft

GROUT
Composition & Proportions Type I Portland with Bentonite Gel
Tremied (Y / N)
Interval BGS 1.5-24 ft

CENTRALIZERS (Y /(N))
Depth(s) BGS

SEAL
Type Medium Bentonite Chips
Source Pure Gold (50 lbs)

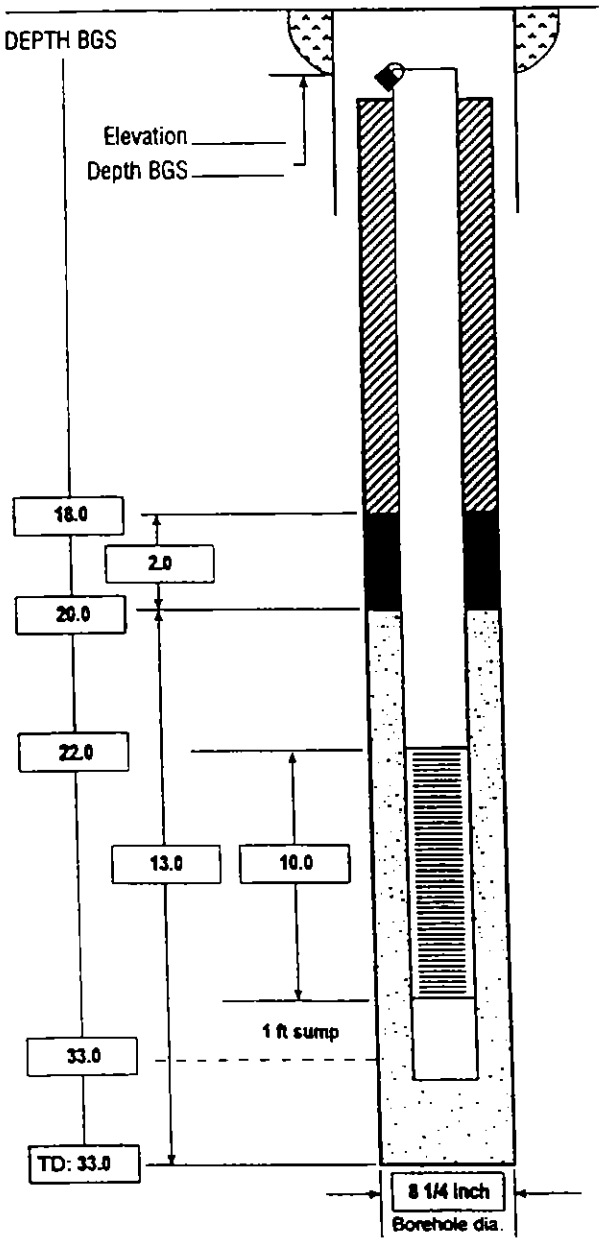
FILTER PACK
Type Silica Sand (26-39 ft)
Amount Used 450 lbs
Tremied (Y /(N))
Source UNIMIN
Gr. Size Dist. 20-40

SCREEN
Type Stainless Steel Wrapped
Diameter 2 inch
Slot Size & Type 0.010 inch
Interval BGS 28-38 ft

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation: Kelly Air Force Base
Site: Kirk West of Cupples
Project Number: 111494.B1.30
Drilling Contractor: JEDI
Field Hydrogeologist: B. Rahe

Well Number: SS050MW338
Client/Project: Zone 5 RI Mod 12
Starting: date 11/30/98 time
Completion: date 11/30/98 time
Well Coordinates: 674.99



RISER PIPE
Type: PVC and Stainless Steel
Diameter: 2 inch
Total Length (TOC to TOS): PVC 0-12 ft, Stainless Riser 12-22 ft

GROUT
Composition & Proportions:
Tremied (Y / N)
Interval BGS: 15-24 ft

CENTRALIZERS (Y /(N))
Depth(s) BGS:

SEAL
Type: Medium Bentonite Chips
Source: Pure Gold (50 lbs)

FILTER PACK
Type: Silica Sand
Amount Used: 450 lbs
Tremied (Y /(N))
Source: UNIMIN
Gr. Size Dist.: 20-40

SCREEN
Type: Stainless Steel Wrapped
Diameter: 2 inch
Slot Size & Type: 0.010 inch
Interval BGS: 22-32 ft

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation Kelly Air Force Base

Well Number SS050MW339 (MW12-9)

Site Menefee East of Cupples

Client/Project Zone 5 RI Mod 12

Project Number 111494.B1.30

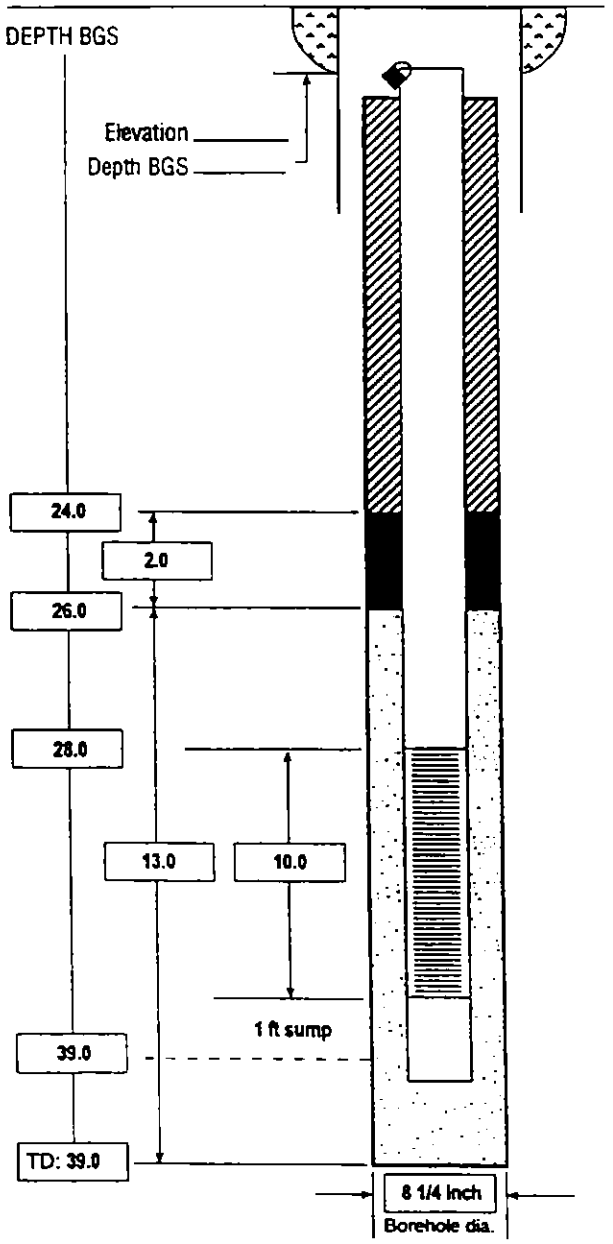
Starting date 12/2/98 time

Drilling Contractor JEDI

Completion date 12/2/98 time

Field Hydrogeologist B. Rahe

Well Coordinates 674.8



RISER PIPE
Type PVC
Diameter 2 inch
Total Length (TOC to TOS) 0-28 ft

GROUT
Composition & Proportions
Tremied (Y / N)
Interval BGS

CENTRALIZERS (Y /(N))
Depth(s) BGS

SEAL
Type Medium Bentonite Chips (50 lbs)
Source Pure Gold

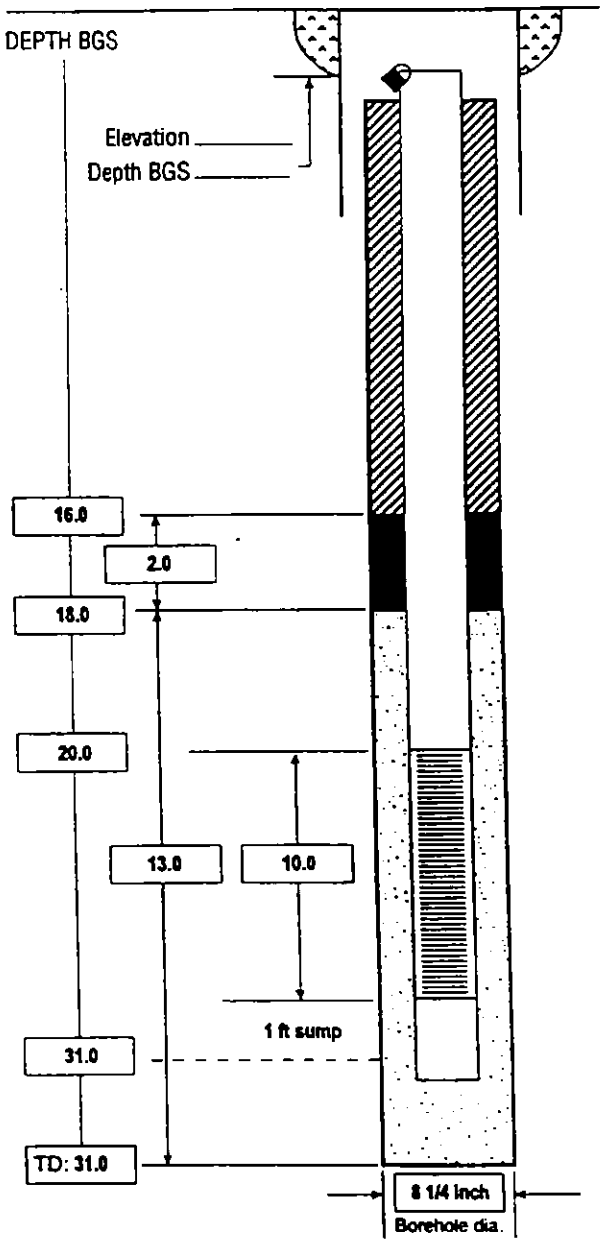
FILTER PACK
Type Silica Sand
Amount Used 500 lbs
Tremied (Y /(N))
Source UNIMIN
Gr. Size Dist. 20-40

SCREEN
Type Stainless Steel Wrapped
Diameter 2 inch
Slot Size & Type 0.010 inch
Interval BGS 28-38 ft

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation: Kelly Air Force Base
Site: Village South of Bedford
Project Number: 111494.B1.30
Drilling Contractor: JEDI
Field Hydrogeologist: B. Rahe

Well Number: SS050MW340 (MW12-10)
Client/Project: Zone 5 RI Mod 12
Starting: date 12/11/98 time
Completion: date 12/11/98 time
Well Coordinates: 669.44



RISER PIPE
Type: PVC
Diameter: 2 inch
Total Length (TOC to TOS): 0-20 ft

GROUT
Composition & Proportions:
Tremied (Y / N)
Interval BGS:

CENTRALIZERS (Y /(N))
Depth(s) BGS:

SEAL
Type: Medium Bentonite Chips (50 lbs)
Source: Pure Gold

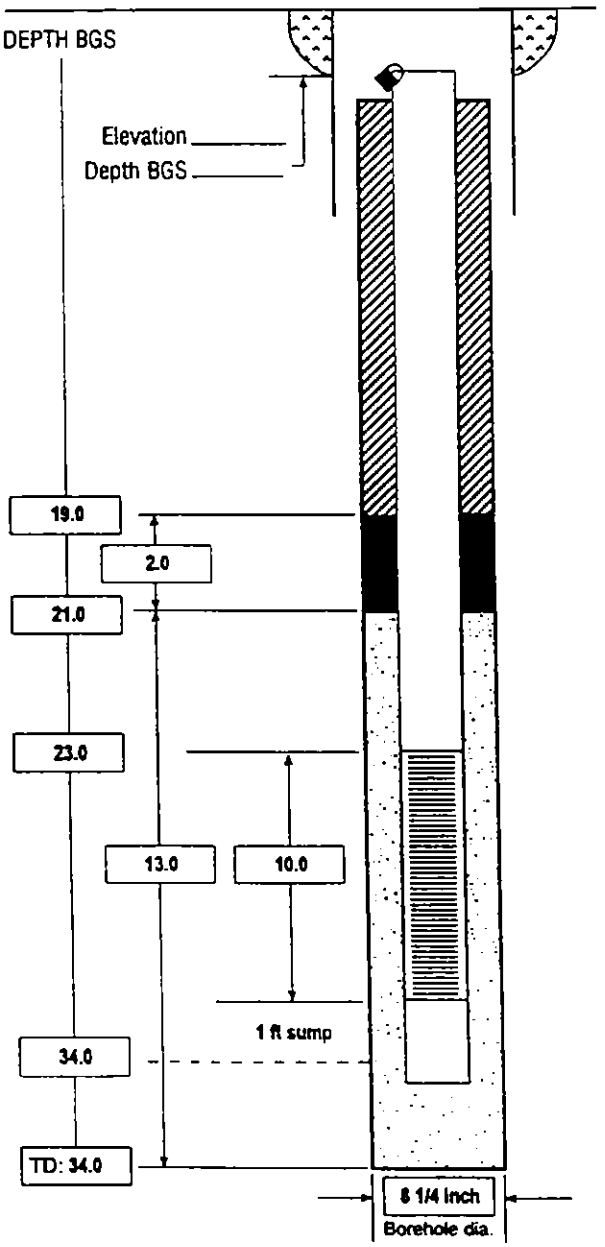
FILTER PACK
Type: Silica Sand (18-31 ft)
Amount Used: 450 lbs
Tremied (Y /(N))
Source: UNIMIN
Gr. Size Dist.: 20-40

SCREEN
Type: Stainless Steel Wrapped
Diameter: 2 inch
Slot Size & Type: 0.010 inch
Interval BGS: 20-30 ft

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation: Kelly Air Force Base
Site: Darby East of Cupples
Project Number: 111494.B1.30
Drilling Contractor: JEDI
Field Hydrogeologist: B. Rahe

Well Number: SS050MW341 (MW12-11)
Client/Project: Zone 5 RI Mod 12
Starting: date 12/14/98 time
Completion: date 12/15/98 time
Well Coordinates: 663.15



RISER PIPE
Type: PVC and Stainless Steel
Diameter: 2 inch
Total Length (TOC to TOS): 0-23 ft (Stainless 18-23 ft)

GROUT
Composition & Proportions:
Tremied (Y / N)
Interval BGS:

CENTRALIZERS (Y /(N))
Depth(s) BGS:

SEAL
Type: Medium Bentonite Chips
Source: Pure Gold

FILTER PACK
Type: Silica Sand
Amount Used:
Tremied (Y /(N))
Source: UNIMIN
Gr. Size Dist.: 20-40

SCREEN
Type: Stainless Steel Wrapped
Diameter: 2 inch
Slot Size & Type: 0.010 inch
Interval BGS: 23-33 ft

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation: Kelly Air Force Base

Site: Menefee North of Sonic Hamburger Restaurant

Project Number: 111494.B1.30

Drilling Contractor: JEDI

Field Hydrogeologist: B. Rahe

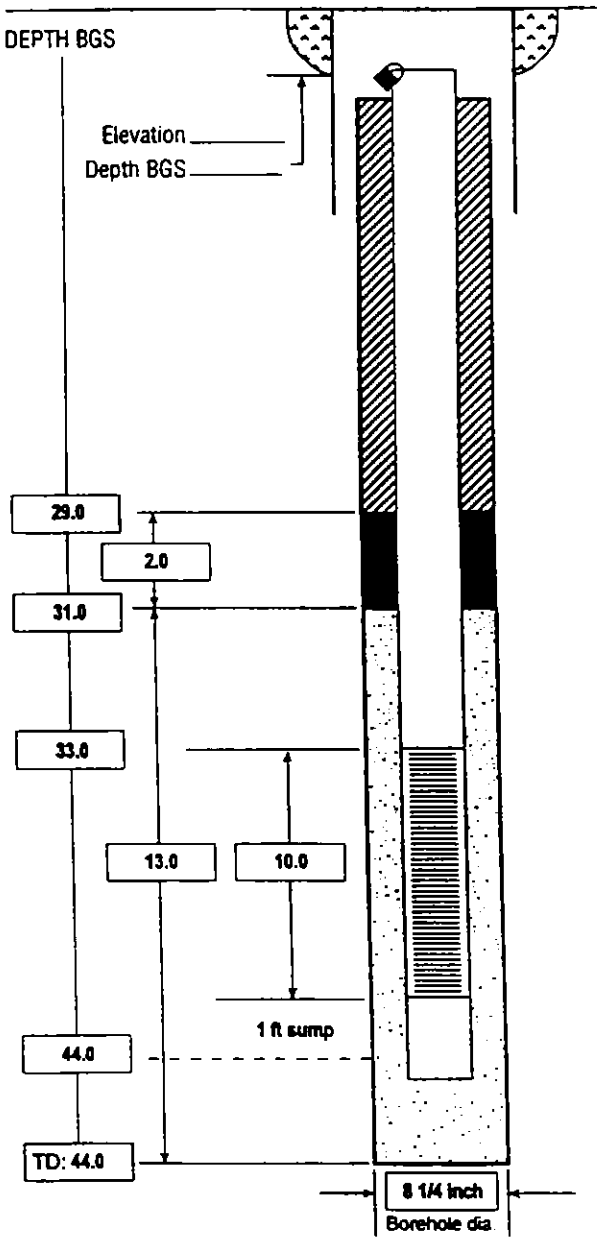
Well Number: SS050MW342

Client/Project: Zone 5 RI Mod 12

Starting: date 11/18/98 time

Completion: date 11/19/98 time

Well Coordinates: 685.19



RISER PIPE
Type: PVC and Stainless Steel
Diameter: 2 Inch
Total Length (TOC to TOS): 0-33 ft (Stainless 23-33 ft)

GROUT
Composition & Proportions:
Tremied (Y / N)
Interval BGS:

CENTRALIZERS (Y /(N))
Depth(s) BGS:

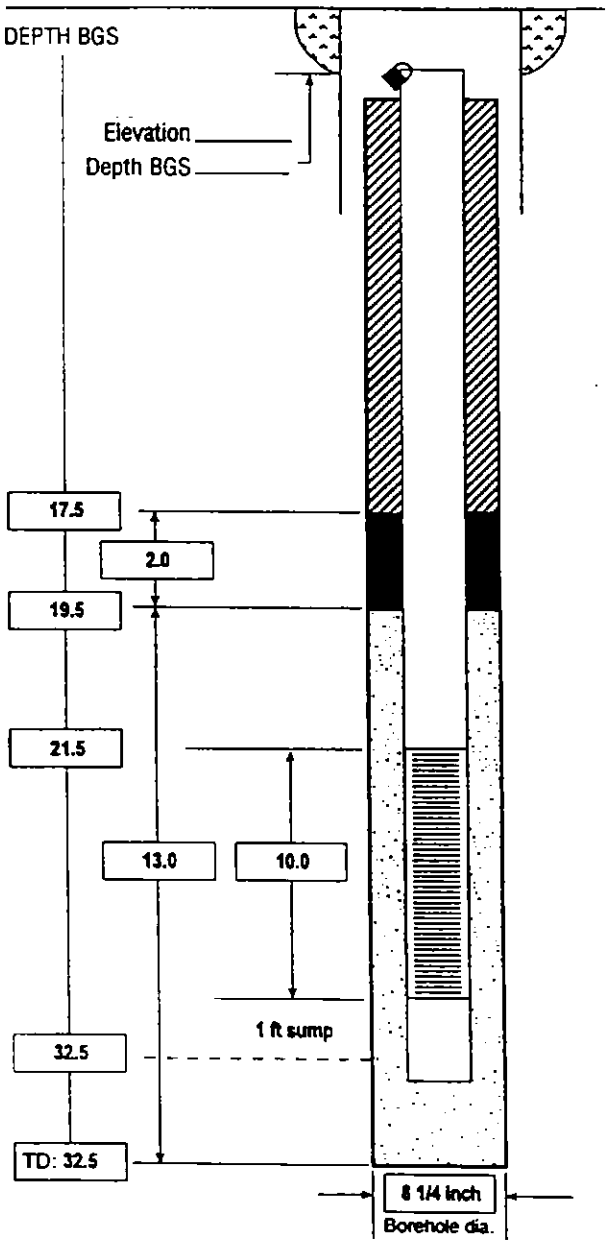
SEAL
Type: Medium Bentonite Chips
Source: Pure Gold

FILTER PACK
Type: Silica Sand
Amount Used: 450 lbs
Tremied (Y /(N))
Source: UNIMIN
Gr. Size Dist.: 20-40

SCREEN
Type: Stainless Steel Wrapped
Diameter: 2 Inch
Slot Size & Type: 0.010 Inch
Interval BGS: 33-43 ft

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation: Kelly Air Force Base
Well Number: SS050MW343 (MW12-13)
Site: Wescott North of Menefee
Client/Project: Zone 5 RI Mod 12
Project Number: 111494.B1.30
Starting: date 12/4/98 time
Drilling Contractor: JEDI
Completion: date 12/4/98 time
Field Hydrogeologist: B. Rahe
Well Coordinates: 693.23



RISER PIPE
Type: PVC and Stainless Steel
Diameter: 2 inch
Total Length (TOC to TOS): 0-21.5 ft

GROUT
Composition & Proportions:
Tremied (Y / N)
Interval BGS:

CENTRALIZERS (Y / N)
Depth(s) BGS:

SEAL
Type: Medium Bentonite Chips 50 lbs
Source: Pure Gold

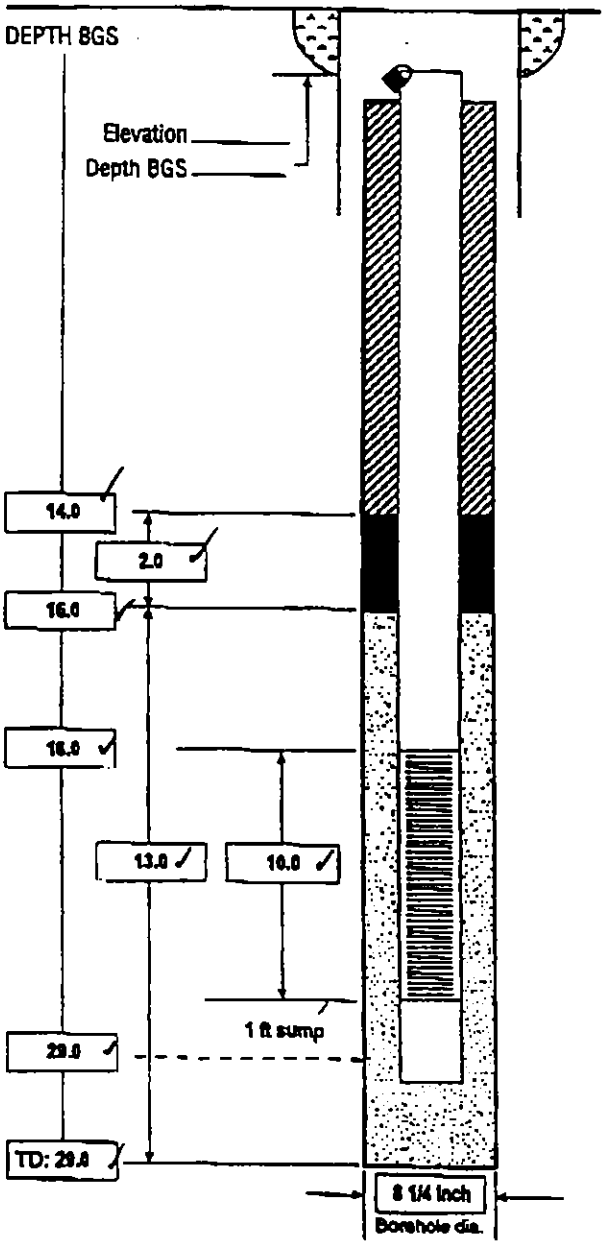
FILTER PACK
Type: Silica Sand (19.5-32.5 ft)
Amount Used: 500 lbs
Tremied (Y / N)
Source: UNIMIN
Gr. Size Dist.: 20-40

SCREEN
Type: Stainless Steel Wrapped
Diameter: 2 inch
Slot Size & Type: 0.010 inch
Interval BGS: 21.5-31.5 ft

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush-Mount

Installation: Kelly Air Force Base
Site: END OF √ ALTGELT ST STREET
Project Number: 111494.B1.30
Drilling Contractor: JEDI
Field Hydrogeologist: B. Rahe

Well Number: SS050MW344 (MW12-14)
Client/Project: Zone 5 RI Mod 12
Starting: date 11/23/98 time
Completion: date 11/23/98 time
Well Coordinates: 695.44



RISER PIPE
Type: PVC ✓
Diameter: 2 inch ✓
Total Length (TOC to TOS): 0-18 ft ✓

GROUT
Composition & Proportions:
Tremied (Y / N) ✓
Interval BGS:

CENTRALIZERS (Y / N) ✓
Depth(s) BGS:

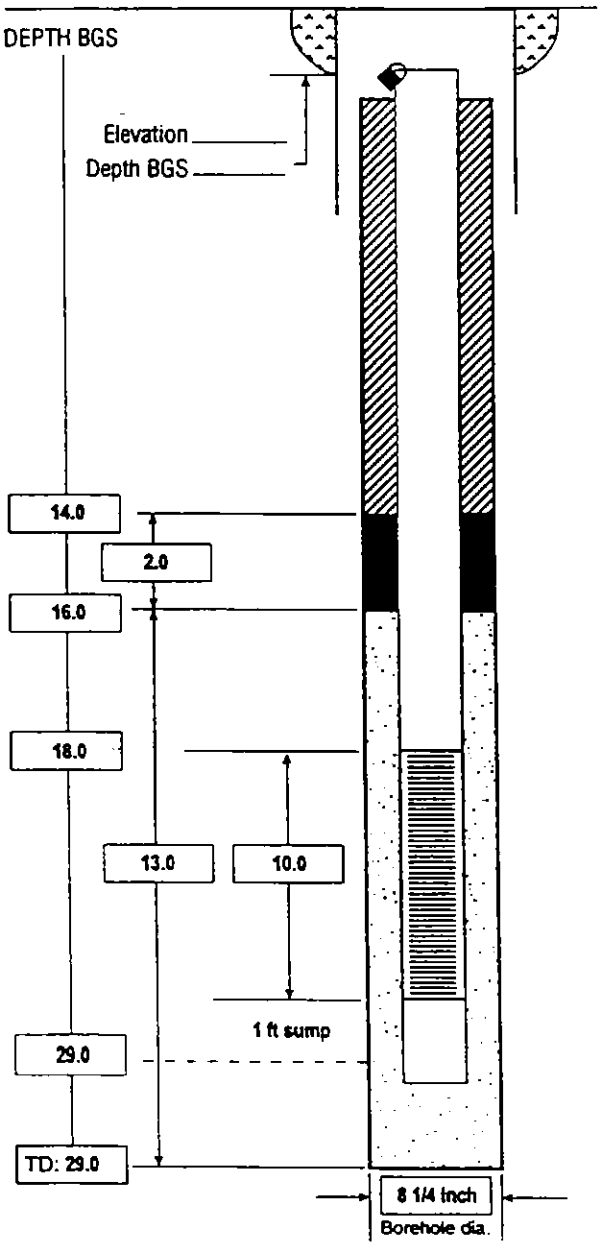
SEAL
Type: Medium Bentonite Chips ✓
Source: Pure Gold ✓

FILTER PACK
Type: Silica Sand (16-29 ft) ✓
Amount Used: 450 lbs ✓
Tremied (Y / N) ✓
Source: UNIMIN ✓
Gr. Size Dist.: 20-40 ✓

SCREEN
Type: Stainless Steel Wrapped ✓
Diameter: 2 inch ✓
Slot Size & Type: 0.010 inch ✓
Interval BGS: 18-28 ft ✓

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation: Kelly Air Force Base
Well Number: SS050MW344 (MW12-14)
Site: End of Valencia Street
Client/Project: Zone 5 RI Mod 12
Project Number: 111494.B1.30
Starting: date 11/23/98 time
Drilling Contractor: JEDI
Completion: date 11/23/98 time
Field Hydrogeologist: B. Rahe
Well Coordinates: 695.44



RISER PIPE
Type: PVC
Diameter: 2 inch
Total Length (TOC to TOS): 0-18 ft

GROUT
Composition & Proportions:
Tremied (Y / N)
Interval BGS:

CENTRALIZERS (Y / N)
Depth(s) BGS:

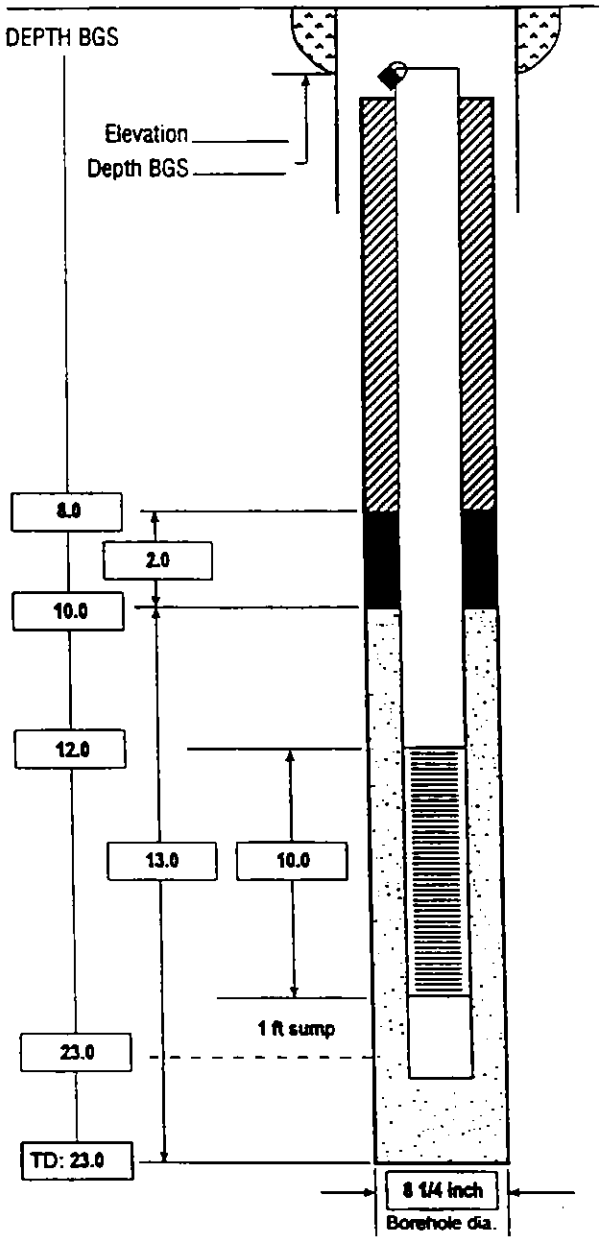
SEAL
Type: Medium Bentonite Chips
Source: Pure Gold

FILTER PACK
Type: Silica Sand (16-29 ft)
Amount Used: 450 lbs
Tremied (Y / N)
Source: UNIMIN
Gr. Size Dist.: 20-40

SCREEN
Type: Stainless Steel Wrapped
Diameter: 2 inch
Slot Size & Type: 0.010 inch
Interval BGS: 18-28 ft

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation: Kelly Air Force Base
Well Number: SS050MW345 (MW12-15)
Site: Guanajuato North of Highway 90
Client/Project: Zone 5 RI Mod 12
Project Number: 111494.B1.30
Starting: date 12/7/98 time
Drilling Contractor: JEDI
Completion: date 12/7/98 time
Field Hydrogeologist: B. Rahe
Well Coordinates: 685.66



RISER PIPE
Type: PVC
Diameter: 2 inch
Total Length (TOC to TOS): 0-12 ft

GROUT
Composition & Proportions:
Tremied (Y / N)
Interval BGS:

CENTRALIZERS (Y / N)
Depth(s) BGS:

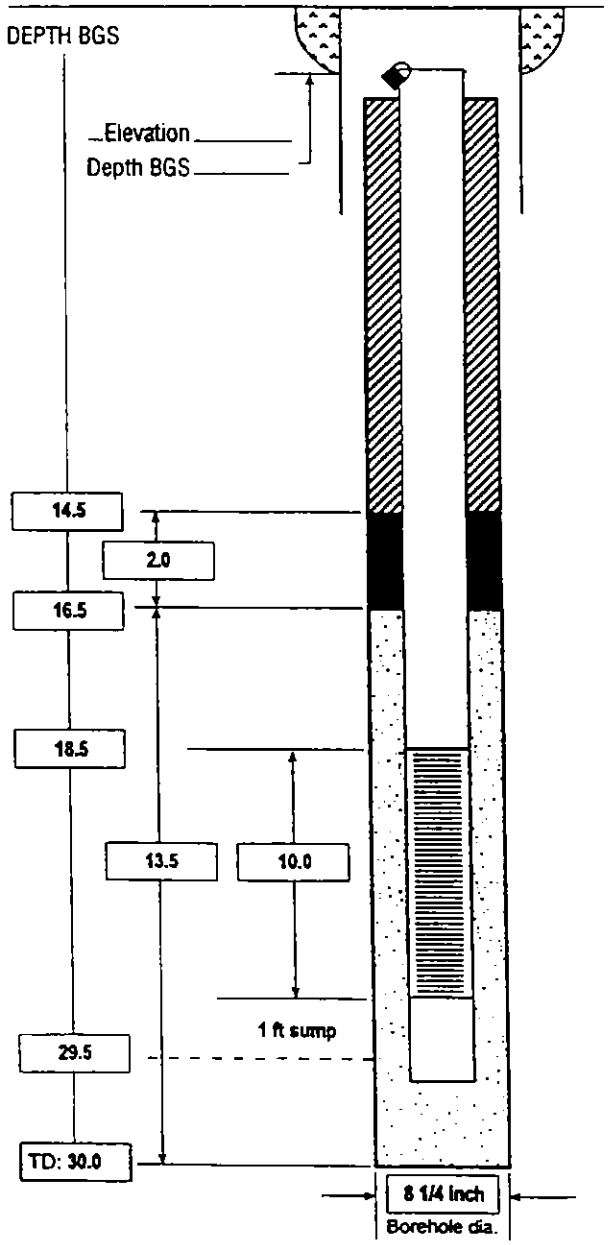
SEAL
Type: Medium Bentonite Chips
Source: Pure Gold

FILTER PACK
Type: Silica Sand
Amount Used: 450 lbs
Tremied (Y / N)
Source: UNIMIN
Gr. Size Dist.: 20-40

SCREEN
Type: Stainless Steel Wrapped
Diameter: 2 inch
Slot Size & Type: 0.010 inch
Interval BGS: 12-22 ft

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation: Kelly Air Force Base
Well Number: SS050MW468
Site: West of Fuels Management
Client/Project: Zone 5 RI Mod 12
Project Number: 111494.B1.30
Starting: date 12/7/98 time
Drilling Contractor: JEDI
Completion: date 12/7/98 time
Field Hydrogeologist: B. Rahe
Well Coordinates: 696, 52



RISER PIPE
Type: PVC
Diameter: 2 inch
Total Length (TOC to TOS): 0-18.5 ft

GROUT
Composition & Proportions:
Tremied (Y / N)
Interval BGS:

CENTRALIZERS (Y /(N))
Depth(s) BGS:

SEAL
Type: Medium Bentonite Chips
Source: Pure Gold

FILTER PACK
Type: Silica Sand
Amount Used: 450 lbs
Tremied (Y /(N))
Source: UNIMIN
Gr. Size Dist.: 20-40

SCREEN
Type: Stainless Steel Wrapped
Diameter: 2 inch
Slot Size & Type: 0.010 inch
Interval BGS: 18.5-28.5 ft

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation: Kelly Air Force Base

Site: Southwest of Building 1414 Outside Fence

Project Number: 111494.B1.30

Drilling Contractor: JEDI

Field Hydrogeologist: B. Rahe

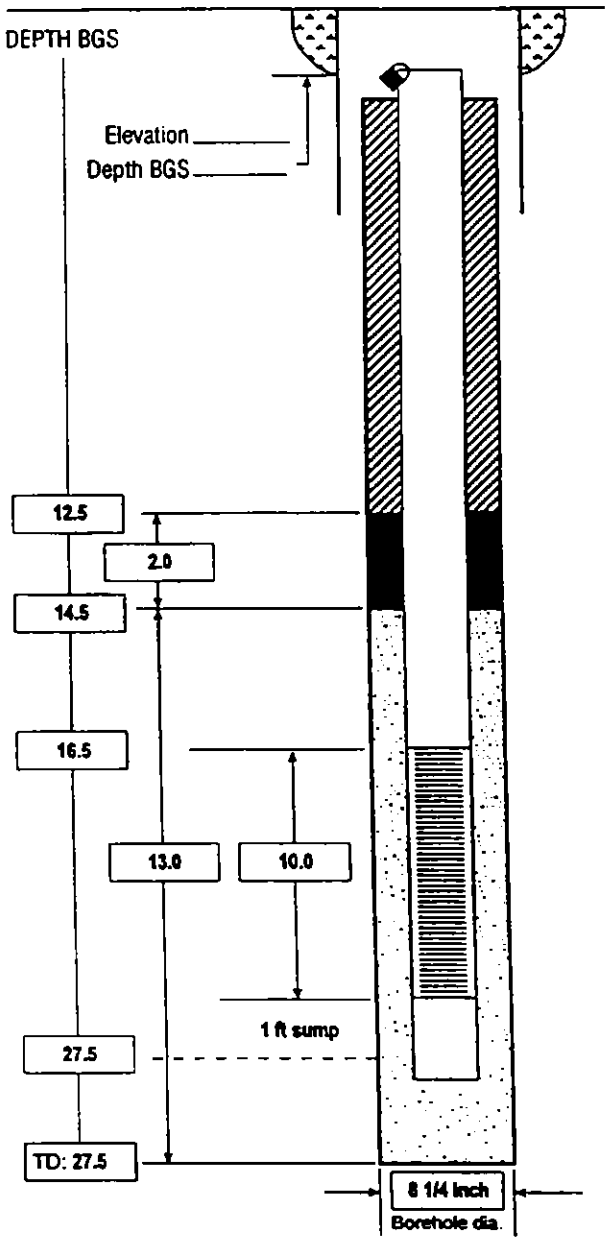
Well Number: SS050MW469

Client/Project: Zone 5 RI Mod 12

Starting: date 11/20/98 time

Completion: date 11/20/98 time

Well Coordinates: 694.24



RISER PIPE
Type: PVC
Diameter: 2 inch
Total Length (TOC to TOS): 0-16.5 ft

GROUT
Composition & Proportions: Cement Portland with Bentonite Gel as per Compliance Plans
Tremied (Y / N)
Interval BGS:

CENTRALIZERS (Y / N)
Depth(s) BGS:

SEAL
Type: Medium Bentonite Chips
Source: Pure Gold

FILTER PACK
Type: Silica Sand (14.5-27.5 ft)
Amount Used: 450 lbs
Tremied (Y / N)
Source: UNIMIN
Gr. Size Dist.: 20-40

SCREEN
Type: Stainless Steel Wrapped
Diameter: 2 inch
Slot Size & Type: 0.010 inch
Interval BGS: 16.5-26.5 ft

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation: Kelly Air Force Base

Well Number: SS050MW470 (MW12-3)

Site: 150 yards South of Building 1414

Client/Project: Zone 5 RI Mod 12

Project Number: 111494.B1.30

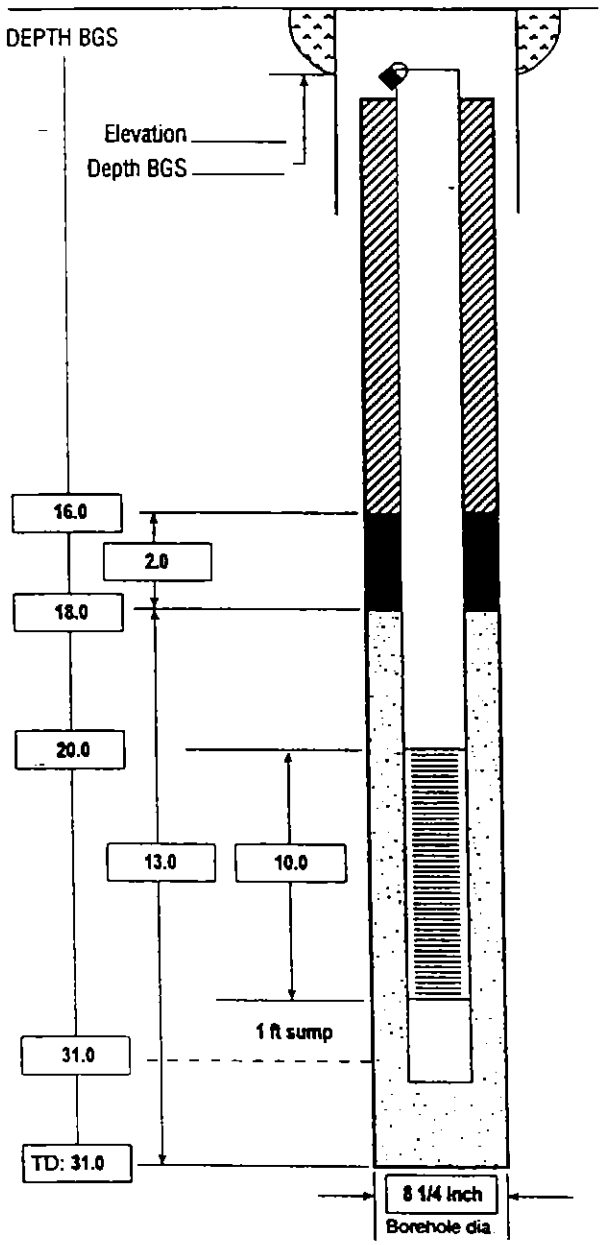
Starting: date 11/16/98 time

Drilling Contractor: JEDI

Completion: date 11/16/98 time

Field Hydrogeologist: B. Rahe

Well Coordinates: 695.16



RISER PIPE
Type: PVC
Diameter: 2 Inch
Total Length (TOC to TOS): 0-20 ft

GROUT
Composition & Proportions:
Tremied (Y / N)
Interval BGS:

CENTRALIZERS (Y / N)
Depth(s) BGS:

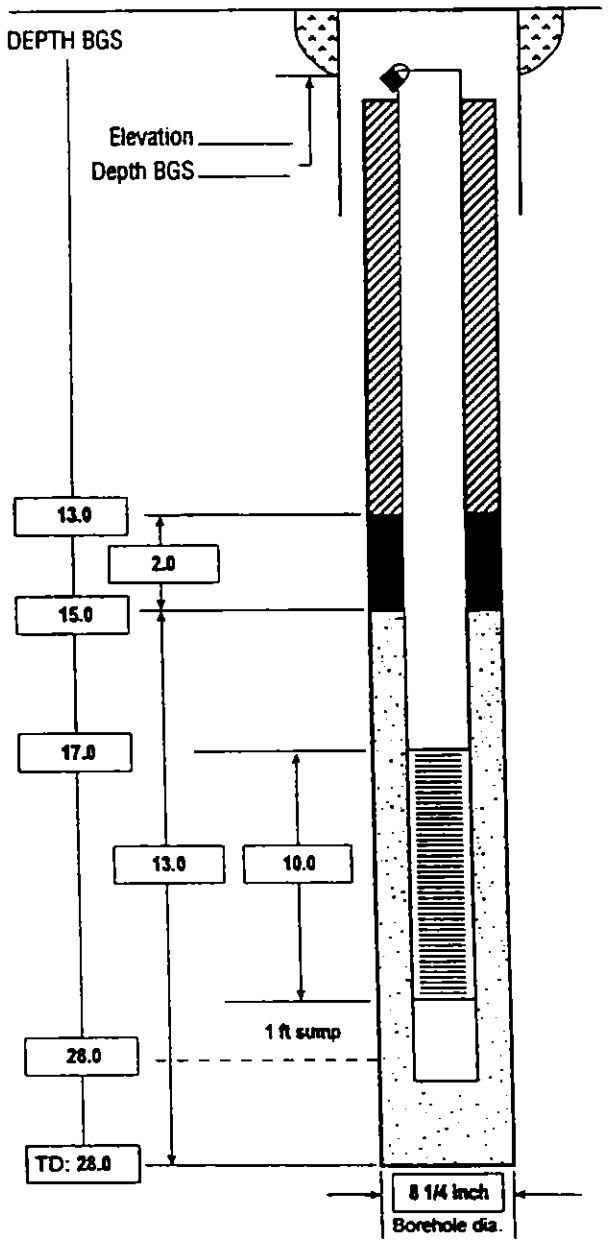
SEAL
Type: Medium Bentonite Chips (50 lbs)
Source: Pure Gold

FILTER PACK
Type: Silica Sand (18-31 ft)
Amount Used: 450 lbs
Tremied (Y / N)
Source: UNIMIN
Gr. Size Dist.: 20-40

SCREEN
Type: Stainless Steel Wrapped
Diameter: 2 Inch
Slot Size & Type: 0.010 Inch
Interval BGS: 20-30 ft

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation: Kelly Air Force Base
Well Number: SS050MW471
Site: South of Building 1414 Next to Yield Sign
Client/Project: Zone 5 RI Mod 12
Project Number: 111494.B1.30
Starting: date 11/17/98 time
Drilling Contractor: JEDI
Completion: date 11/17/98 time
Field Hydrogeologist: B. Rahe
Well Coordinates: 694.23



RISER PIPE
Type: PVC
Diameter: 2 inch
Total Length (TOC to TOS): 0-17 ft

GROUT
Composition & Proportions: Bentonite/Cement Grout as Specified
Tremied (Y / N)
Interval BGS: 1.5-13 ft

CENTRALIZERS (Y /(N))
Depth(s) BGS:

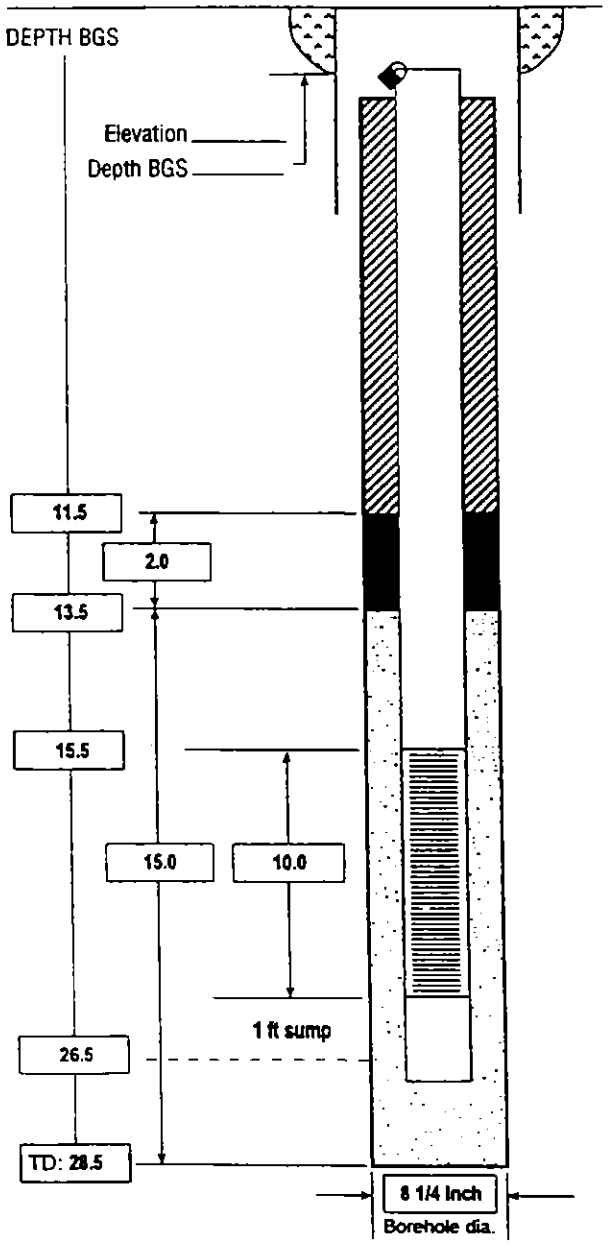
SEAL
Type: Medium Bentonite Chips
Source: Pure Gold

FILTER PACK
Type: Silica Sand (15-28 ft)
Amount Used: 400 lbs
Tremied (Y /(N))
Source: UNIMIN
Gr. Size Dist.: 20-40

SCREEN
Type: Stainless Steel Wrapped
Diameter: 2 inch
Slot Size & Type: 0.010 inch
Interval BGS: 17-27 ft

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation: Kelly Air Force Base
Well Number: SS050MW472 (MW12-16)
Site: Outside Base Ops by Tree
Client/Project: Zone 5 RI Mod 12
Project Number: 111494.B1.30
Starting: date 11/13/98 time
Drilling Contractor: JEDI
Completion: date 11/13/98 time
Field Hydrogeologist: B. Rahe
Well Coordinates: 678.64



RISER PIPE
Type: PVC (box with NSF stamp)
Diameter: 2 inch
Total Length (TOC to TOS): 0-15.5 ft

GROUT
Composition & Proportions:
Tremied (Y / N)
Interval BGS:

CENTRALIZERS (Y / N)
Depth(s) BGS:

SEAL
Type: Medium Bentonite Chips
Source: Pure Gold

FILTER PACK
Type: Silica Sand
Amount Used: 450 lbs
Tremied (Y / N)
Source: UNIMIN
Gr. Size Dist.: 20-40

SCREEN
Type: Stainless Steel Wrapped
Diameter: 2 inch
Slot Size & Type: 0.010 Inch
Interval BGS: 15.5-26.5 ft

CH2MHILL MONITORING WELL CONSTRUCTION LOG Standard Flush Mount

Installation: Kelly Air Force Base

Site: Across Street from Base Ops by Yield Sign (Site ST010)

Project Number: 111494.B1.30

Drilling Contractor: JEDI

Field Hydrogeologist: B. Rahe

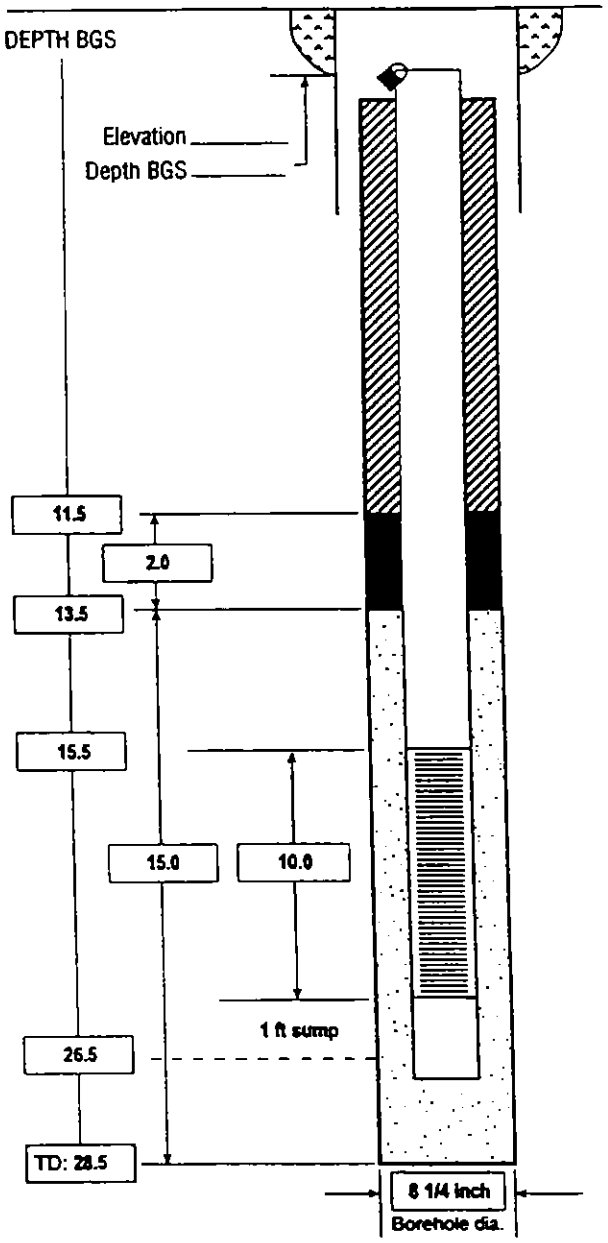
Well Number: SS050MW473

Client/Project: Zone 5 RI Mod 12

Starting: date 11/13/98 time

Completion: date 11/13/98 time

Well Coordinates: 678.77



RISER PIPE
Type: PVC (no stainless riser required)
Diameter: 2 inch
Total Length (TOC to TOS): 0-15.5 ft (PVC riser was NSF stamped on box)

GROUT
Composition & Proportions:
Tremied (Y / N)
Interval BGS:

CENTRALIZERS (Y /(N))
Depth(s) BGS:

SEAL
Type: Medium Bentonite Chips 11.5-13.5 ft (50 lbs)
Source: Pure Gold

FILTER PACK
Type: Silica Sand
Amount Used: 450 lbs
Tremied (Y /(N))
Source: UNIMIN
Gr. Size Dist.: 20-40

SCREEN
Type: Stainless with NSF Stamp on Box
Diameter: 2 inch
Slot Size & Type: 0.010 inch
Interval BGS: 15.5-25.5 ft

Attachment B
Analytical Data Summary Sheets

Analytical Data Summary
Volatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

Parameter		StationID	SS025SB017	SS025SB017	SS025SB018	SS025SB018	SS025SB019	SS025SB019	SS025SB020
		Alias	SB12-1	SB12-1	SB12-2	SB12-2	SB12-3	SB12-3	SB12-4
		SampleID	SIB018	SIB019	SIB021	SIB022	SIB040	SIB041	SIB025
		Depth	0-2	20-22	2-4	10-12	2-4	26-28	2-4
CHLOROMETHANE	UG/KG		13 U	10 U	13 U	12 U	13 U	12 U	13 U
VINYL CHLORIDE	UG/KG		13 U	10 U	13 U	12 U	13 U	12 U	13 U
BROMOMETHANE	UG/KG		13 UJ	10 UJ	13 UJ	12 UJ	13 U	12 U	13 UJ
CHLOROETHANE	UG/KG		13 U	10 U	13 U	12 U	13 U	12 U	13 UJ
1,1-DICHLOROETHENE	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 U
ACETONE	UG/KG		13 U	10 U	83 UJ	12 UJ	43 U	12 U	160 U
CARBON DISULFIDE	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 UJ
METHYLENE CHLORIDE	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 UJ
1,1-DICHLOROETHANE	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 U
VINYL ACETATE	UG/KG		13 U	10 U	13 U	12 U	13 UJ	12 UJ	13 U
TOTAL 1,2-DICHLOROETHENE	UG/KG		7 U	5 U	35 -	6 U	6 U	6 U	30 -
METHYL ETHYL KETONE (2-BUTANONE)	UG/KG		13 U	10 U	14 UJ	12 UJ	13 U	12 U	24 J
CHLOROFORM	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 U
1,1,1-TRICHLOROETHANE	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 UJ
CARBON TETRACHLORIDE	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 UJ
BENZENE	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 U
1,2-DICHLOROETHANE	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 U
TRICHLOROETHYLENE (TCE)	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 U
1,2-DICHLOROPROPANE	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 U
BROMODICHLOROMETHANE	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 U
cis-1,3-DICHLOROPROPENE	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 U
METHYL ISOBUTYL KETONE (4-METHYL-2-PENTANONE)	UG/KG		13 U	10 U	13 U	12 U	13 U	12 U	13 U
TOLUENE	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 U
trans-1,3-DICHLOROPROPENE	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 U
1,1,2-TRICHLOROETHANE	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 U
TETRACHLOROETHYLENE(PCE)	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 U
2-HEXANONE	UG/KG		13 U	10 U	13 U	12 U	13 U	12 U	13 U
DIBROMOCHLOROMETHANE	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 U
CHLOROBENZENE	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 U
ETHYLBENZENE	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 U
XYLENES, TOTAL	UG/KG		7 U	5 U	6 U	6 U	6 U	6 U	6 U

Analytical Data Summary
Volatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS025SB017	SS025SB017	SS025SB018	SS025SB018	SS025SB019	SS025SB019	SS025SB020
	Alias	SB12-1	SB12-1	SB12-2	SB12-2	SB12-3	SB12-3	SB12-4
	SampleID	SIB018	SIB019	SIB021	SIB022	SIB040	SIB041	SIB025
	Depth	0-2	20-22	2-4	10-12	2-4	26-28	2-4
Parameter								
STYRENE	UG/KG	7 U	5 U	6 U	6 U	6 U	6 U	6 U
BROMOFORM	UG/KG	7 U	5 U	6 U	6 U	6 U	6 U	6 U
1,1,2,2-TETRACHLOROETHANE	UG/KG	7 U	5 U	6 U	6 U	6 U	6 U	6 U

Analytical Summary
Volatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS025SB020	SS025SB021	SS025SB021	SS025SB022	SS025SB022	SS025SB023	SS025SB023
	Alias	SB12-4	SB12-5	SB12-5	SB12-6	SB12-6	SB12-7	SB12-7
	SampleID	SIB026	SIB027	SIB028	SIB029	SIB030	SIB009	SIB010FD1
	Depth	22-24	6-8	26-28	6-8	22-24	6-8	6-8
Parameter								
CHLOROMETHANE	UG/KG	11 U	13 U	12 U	13 U	12 U	12 U	12 U
VINYL CHLORIDE	UG/KG	11 U	13 U	12 U	13 U	12 U	12 U	12 U
BROMOMETHANE	UG/KG	11 UJ	13 UJ	12 UJ	13 UJ	12 UJ	12 U	12 U
CHLOROETHANE	UG/KG	11 UJ	13 UJ	12 UJ	13 UJ	12 UJ	12 U	12 U
1,1-DICHLOROETHENE	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U
ACETONE	UG/KG	11 U	54 U	12 U	48 U	12 U	12 U	12 U
CARBON DISULFIDE	UG/KG	6 UJ	6 UJ	6 UJ	6 UJ	6 UJ	6 U	6 U
METHYLENE CHLORIDE	UG/KG	6 UJ	6 UJ	6 UJ	6 UJ	6 UJ	6 U	6 U
1,1-DICHLOROETHANE	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U
VINYL ACETATE	UG/KG	11 U	13 U	12 U	13 U	12 U	12 U	12 U
TOTAL 1,2-DICHLOROETHENE	UG/KG	6 U	6 U	6 U	35 -	12 -	6 U	6 U
METHYL ETHYL KETONE (2-BUTANONE)	UG/KG	11 UJ	13 UJ	12 UJ	13 UJ	12 UJ	12 U	12 U
CHLOROFORM	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U
1,1,1-TRICHLOROETHANE	UG/KG	6 UJ	6 UJ	6 UJ	6 UJ	6 UJ	6 U	6 U
CARBON TETRACHLORIDE	UG/KG	6 UJ	6 UJ	6 UJ	6 UJ	6 UJ	6 U	6 U
BENZENE	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U
1,2-DICHLOROETHANE	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U
TRICHLOROETHYLENE (TCE)	UG/KG	6 U	7 -	6 U	13 -	8 -	6 U	6 U
1,2-DICHLOROPROPANE	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U
BROMODICHLOROMETHANE	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U
cis-1,3-DICHLOROPROPENE	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U
METHYL ISOBUTYL KETONE (4-METHYL-2-PENTANONE)	UG/KG	11 U	13 U	12 U	13 U	12 U	12 U	12 U
TOLUENE	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U
trans-1,3-DICHLOROPROPENE	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U
1,1,2-TRICHLOROETHANE	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U
TETRACHLOROETHYLENE(PCE)	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U
2-HEXANONE	UG/KG	11 U	13 U	12 U	13 U	12 U	12 U	12 U
DIBROMOCHLOROMETHANE	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U
CHLOROBENZENE	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U
ETHYLBENZENE	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U
XYLENES, TOTAL	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U

Analytical Data Summary
Volatile Organics In Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS025SB020	SS025SB021	SS025SB021	SS025SB022	SS025SB022	SS025SB023	SS025SB023
	Alias	SB12-4	SB12-5	SB12-5	SB12-6	SB12-6	SB12-7	SB12-7
	SampleID	SIB026	SIB027	SIB028	SIB029	SIB030	SIB009	SIB010FD1
	Depth	22-24	6-8	26-28	6-8	22-24	6-8	6-8
Parameter								
STYRENE	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U
BROMOFORM	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U
1,1,2,2-TETRACHLOROETHANE	UG/KG	6 U	6 U	6 U	6 U	6 U	6 U	6 U

Analytical Data Summary
Volatile Organics In Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

Parameter		StationID	SS025SB023	SS025SB024	SS025SB024	SS025SB025	SS025SB025	SS025SB025	SS025SB028
		Alias	SB12-7	SB12-8	SB12-8	SB12-9	SB12-9	SB12-9	SB12-10
		SampleID	SIB011	SIB004	SIB005	SIB006	SIB006LR1	SIB007	SIB042
		Depth	22-24	4-6	20-22	4-6	4-6	20-22	6-8
CHLOROMETHANE	UG/KG		11 U	13 UJ	11 UJ	14 UJ		12 U	13 U
VINYL CHLORIDE	UG/KG		11 U	13 U	11 U	14 U		12 U	13 U
BROMOMETHANE	UG/KG		11 U	13 U	11 U	14 U		12 U	13 U
CHLOROETHANE	UG/KG		11 U	13 U	11 U	14 U		12 U	13 U
1,1-DICHLOROETHENE	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
ACETONE	UG/KG		11 U	37 U	11 U	170 U		12 U	57 U
CARBON DISULFIDE	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
METHYLENE CHLORIDE	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
1,1-DICHLOROETHANE	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
VINYL ACETATE	UG/KG		11 U	13 U	11 U	14 U		12 U	13 UJ
TOTAL 1,2-DICHLOROETHENE	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
METHYL ETHYL KETONE (2-BUTANONE)	UG/KG		11 U	13 U	11 U	15 -		12 U	13 U
CHLOROFORM	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
1,1,1-TRICHLOROETHANE	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
CARBON TETRACHLORIDE	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
BENZENE	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
1,2-DICHLOROETHANE	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
TRICHLOROETHYLENE (TCE)	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
1,2-DICHLOROPROPANE	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
BROMODICHLOROMETHANE	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
cis-1,3-DICHLOROPROPENE	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
METHYL ISOBUTYL KETONE (4-METHYL-2-PENTANONE)	UG/KG		11 U	13 U	11 U	14 U		12 U	13 U
TOLUENE	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
trans-1,3-DICHLOROPROPENE	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
1,1,2-TRICHLOROETHANE	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
TETRACHLOROETHYLENE(PCE)	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
2-HEXANONE	UG/KG		11 U	13 U	11 U	14 U		12 U	13 U
DIBROMOCHLOROMETHANE	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
CHLOROBENZENE	UG/KG		5 U	6 U	6 U		86 -	6 U	6 U
ETHYLBENZENE	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U
XYLENES, TOTAL	UG/KG		5 U	6 U	6 U	7 U		6 U	6 U

Analytical Data Summary
Volatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS025SB023	SS025SB024	SS025SB024	SS025SB025	SS025SB025	SS025SB025	SS025SB026
	Alias	SB12-7	SB12-8	SB12-8	SB12-9	SB12-9	SB12-9	SB12-10
	SampleID	SIB011	SIB004	SIB005	SIB006	SIB006LR1	SIB007	SIB042
	Depth	22-24	4-6	20-22	4-6	4-6	20-22	6-8
Parameter								
STYRENE	UG/KG	5 U	6 U	6 U	7 U		6 U	6 U
BROMOFORM	UG/KG	5 U	6 U	6 U	7 U		6 U	6 U
1,1,2,2-TETRACHLOROETHANE	UG/KG	5 U	6 U	6 U	7 U		6 U	6 U

Analytical Data Summary
Volatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

Parameter	StationID	SS025SB028	SS025SB027	SS025SB027	SS025SB028	SS025SB028	SS045SB017	SS045SB017
	Alias	SB12-10	SB12-14	SB12-14	SB12-15	SB12-15	SB12-11	SB12-11
	SampleID	SIB043	SIB014	SIB015	SIB012	SIB013	SIB032	SIB032LR1
	Depth	12-14	14-16	26-28	6-8	20-22	2-4	2-4
CHLOROMETHANE	UG/KG	12 U	62 U	57 U	12 U	13 U	13 U	
VINYL CHLORIDE	UG/KG	12 U	62 U	57 U	12 U	13 U	13 U	
BROMOMETHANE	UG/KG	12 U	62 U	57 U	12 U	13 U	13 U	
CHLOROETHANE	UG/KG	12 U	62 U	57 U	12 U	13 U	13 U	
1,1-DICHLOROETHENE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
ACETONE	UG/KG	12 U	62 U	57 U	12 U	13 U	13 U	
CARBON DISULFIDE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
METHYLENE CHLORIDE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
1,1-DICHLOROETHANE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
VINYL ACETATE	UG/KG	12 UJ	62 U	57 U	12 U	13 U	13 U	
TOTAL 1,2-DICHLOROETHENE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
METHYL ETHYL KETONE (2-BUTANONE)	UG/KG	12 U	62 U	57 U	12 U	13 U	13 U	
CHLOROFORM	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
1,1,1-TRICHLOROETHANE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
CARBON TETRACHLORIDE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
BENZENE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
1,2-DICHLOROETHANE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
TRICHLOROETHYLENE (TCE)	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
1,2-DICHLOROPROPANE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
BROMODICHLOROMETHANE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
cis-1,3-DICHLOROPROPENE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
METHYL ISOBUTYL KETONE (4-METHYL-2-PENTANONE)	UG/KG	12 U	62 U	57 U	12 U	13 U	13 U	
TOLUENE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
trans-1,3-DICHLOROPROPENE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
1,1,2-TRICHLOROETHANE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
TETRACHLOROETHYLENE(PCE)	UG/KG	6 U	31 U	29 U	6 U	7 U		460 -
2-HEXANONE	UG/KG	12 U	62 U	57 U	12 U	13 U	13 U	
DIBROMOCHLOROMETHANE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
CHLOROBENZENE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
ETHYLBENZENE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
XYLENES, TOTAL	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	

Analytical Data Summary
Volatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS025SB026	SS025SB027	SS025SB027	SS025SB028	SS025SB028	SS045SB017	SS045SB017
	Alias	SB12-10	SB12-14	SB12-14	SB12-15	SB12-15	SB12-11	SB12-11
	SampleID	SIB043	SIB014	SIB015	SIB012	SIB013	SIB032	SIB032LR1
	Depth	12-14	14-16	26-28	6-8	20-22	2-4	2-4
Parameter								
STYRENE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
BROMOFORM	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	
1,1,2,2-TETRACHLOROETHANE	UG/KG	6 U	31 U	29 U	6 U	7 U	6 U	

Analytical Data Summary
Volatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS045SB017	SS045SB017	SS045SB017	SS045SB018	SS045SB018	SS045SB019	SS045SB019
	Alias	SB12-11	SB12-11	SB12-11	SB12-12	SB12-12	SB12-13	SB12-13
	SampleID	SIB033FD1	SIB033FD1LR1	SIB034	SIB035	SIB036	SIB037	SIB038
	Depth	2-4	2-4	20-21	0-2	20-22	4-6	18-20
Parameter								
CHLOROMETHANE	UG/KG	13 U		11 U	11 U	11 U	11 U	57 U
VINYL CHLORIDE	UG/KG	13 U		11 U	11 U	11 U	11 U	57 U
BROMOMETHANE	UG/KG	13 U		11 U	11 U	11 U	11 U	57 U
CHLOROETHANE	UG/KG	13 U		11 U	11 U	11 U	11 U	57 U
1,1-DICHLOROETHENE	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
ACETONE	UG/KG	13 U		11 U	11 U	11 U	11 U	78 U
CARBON DISULFIDE	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
METHYLENE CHLORIDE	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
1,1-DICHLOROETHANE	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
VINYL ACETATE	UG/KG	13 U		11 UJ	11 U	11 U	11 U	57 U
TOTAL 1,2-DICHLOROETHENE	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
METHYL ETHYL KETONE (2-BUTANONE)	UG/KG	13 U		11 U	11 U	11 U	11 U	57 U
CHLOROFORM	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
1,1,1-TRICHLOROETHANE	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
CARBON TETRACHLORIDE	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
BENZENE	UG/KG	6 U		5 U	5 U	6 U	6 U	380 -
1,2-DICHLOROETHANE	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
TRICHLOROETHYLENE (TCE)	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
1,2-DICHLOROPROPANE	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
BROMODICHLOROMETHANE	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
cis-1,3-DICHLOROPROPENE	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
METHYL ISOBUTYL KETONE (4-METHYL-2-PENTANONE)	UG/KG	13 U		11 U	11 U	11 U	11 U	57 U
TOLUENE	UG/KG	6 U		5 U	5 U	6 U	6 U	40 -
trans-1,3-DICHLOROPROPENE	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
1,1,2-TRICHLOROETHANE	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
TETRACHLOROETHYLENE(PCE)	UG/KG		480 -	6 -	5 U	6 U	6 U	28 U
2-HEXANONE	UG/KG	13 U		11 U	11 U	11 U	11 U	57 U
DIBROMOCHLOROMETHANE	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
CHLOROBENZENE	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
ETHYLBENZENE	UG/KG	6 U		5 U	5 U	6 U	6 U	
XYLENES, TOTAL	UG/KG	6 U		5 U	5 U	6 U	6 U	

Analytical Data Summary
Volatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS045SB017	SS045SB017	SS045SB017	SS045SB018	SS045SB018	SS045SB019	SS045SB019
	Alias	SB12-11	SB12-11	SB12-11	SB12-12	SB12-12	SB12-13	SB12-13
	SampleID	SIB033FD1	SIB033FD1LR1	SIB034	SIB035	SIB036	SIB037	SIB038
	Depth	2-4	2-4	20-21	0-2	20-22	4-6	18-20
Parameter								
STYRENE	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
BROMOFORM	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U
1,1,2,2-TETRACHLOROETHANE	UG/KG	6 U		5 U	5 U	6 U	6 U	28 U

Analytical Data Summary
Volatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

Parameter		StationID	SS045SB019	SS050MW468	SS050MW468	SS050MW469	SS050MW469	SS050MW469	SS050MW470
		Alias	SB12-13	MW12-1	MW12-1	MW12-2	MW12-2	MW12-2	MW12-3
		SampleID	SIB038LR1	SIA042	SIA043	SIA025	SIA028FD1	SIA027	SIA010
		Depth	16-20	2-4	26-26	6-8	6-8	22-24	6-8
CHLOROMETHANE	UG/KG			14 U	11 U	12 U	12 U	12 U	12 U
VINYL CHLORIDE	UG/KG			14 U	11 U	12 U	12 U	12 U	12 U
BROMOMETHANE	UG/KG			14 U	11 U	12 U	12 U	12 U	12 U
CHLOROETHANE	UG/KG			14 U	11 U	12 U	12 U	12 U	12 U
1,1-DICHLOROETHENE	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
ACETONE	UG/KG			160 U	11 U	12 U	12 U	12 U	12 U
CARBON DISULFIDE	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
METHYLENE CHLORIDE	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
1,1-DICHLOROETHANE	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
VINYL ACETATE	UG/KG			14 U	11 U	12 U	12 U	12 U	12 U
TOTAL 1,2-DICHLOROETHENE	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
METHYL ETHYL KETONE (2-BUTANONE)	UG/KG			30 -	11 U	12 U	12 U	12 U	12 U
CHLOROFORM	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
1,1,1-TRICHLOROETHANE	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
CARBON TETRACHLORIDE	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
BENZENE	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
1,2-DICHLOROETHANE	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
TRICHLOROETHYLENE (TCE)	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
1,2-DICHLOROPROPANE	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
BROMODICHLOROMETHANE	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
cis-1,3-DICHLOROPROPENE	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
METHYL ISOBUTYL KETONE (4-METHYL-2-PENTANONE)	UG/KG			14 U	11 U	12 U	12 U	12 U	12 U
TOLUENE	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
trans-1,3-DICHLOROPROPENE	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
1,1,2-TRICHLOROETHANE	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
TETRACHLOROETHYLENE(PCE)	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
2-HEXANONE	UG/KG			14 U	11 U	12 U	12 U	12 U	12 U
DIBROMOCHLOROMETHANE	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
CHLOROBENZENE	UG/KG			7 U	6 U	6 U	6 U	6 U	6 U
ETHYLBENZENE	UG/KG		8800 -	8 -	6 U	6 U	6 U	6 U	6 U
XYLENES, TOTAL	UG/KG		28000 -	7 U	6 U	6 U	6 U	6 U	6 U

Analytical Data Summary
Volatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS045SB019	SS050MW488	SS050MW488	SS050MW469	SS050MW469	SS050MW469	SS050MW470
	Alias	SB12-13	MW12-1	MW12-1	MW12-2	MW12-2	MW12-2	MW12-3
	SampleID	SIB038LR1	SIA042	SIA043	SIA025	SIA026FD1	SIA027	SIA010
	Depth	18-20	2-4	26 26	6 8	6-8	22-24	6-8
Parameter								
STYRENE	UG/KG		7 U	6 U	6 U	6 U	6 U	6 U
BROMOFORM	UG/KG		7 U	6 U	6 U	6 U	6 U	6 U
1,1,2,2-TETRACHLOROETHANE	UG/KG		7 U	6 U	6 U	6 U	6 U	6 U

Analytical Data Summary
Volatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

Parameter	StationID	SS050MW470	SS050MW471	SS050MW471	SS050MW472	SS050MW472	SS050MW473	SS050MW473
	Alias	MW12-3	MW12-18	MW12-18	MW12-18	MW12-16	MW12-17	MW12-17
	SampleID	SIA011	SIA016	SIA017	SIA003	SIA004	SIA005	SIA006
	Depth	20-22	6-8	22-24	0-2	18-20	0-2	18-20
CHLOROMETHANE	UG/KG	10 U	12 U	12 U	12 UJ	11 UJ	13 UJ	11 UJ
VINYL CHLORIDE	UG/KG	10 U	12 U	12 U	12 U	11 U	13 U	11 U
BROMOMETHANE	UG/KG	10 U	12 U	12 U	12 U	11 U	13 U	11 U
CHLOROETHANE	UG/KG	10 U	12 U	12 U	12 U	11 U	13 U	11 U
1,1-DICHLOROETHENE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
ACETONE	UG/KG	10 U	12 U	12 U	12 U	11 U	13 U	11 U
CARBON DISULFIDE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
METHYLENE CHLORIDE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
1,1-DICHLOROETHANE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
VINYL ACETATE	UG/KG	10 U	12 U	12 U	12 U	11 U	13 U	11 U
TOTAL 1,2-DICHLOROETHENE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
METHYL ETHYL KETONE (2-BUTANONE)	UG/KG	10 U	12 U	12 U	12 U	11 U	13 U	11 U
CHLOROFORM	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
1,1,1-TRICHLOROETHANE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
CARBON TETRACHLORIDE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
BENZENE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
1,2-DICHLOROETHANE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
TRICHLOROETHYLENE (TCE)	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
1,2-DICHLOROPROPANE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
BROMODICHLOROMETHANE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
cis-1,3-DICHLOROPROPENE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
METHYL ISOBUTYL KETONE (4-METHYL-2-PENTANONE)	UG/KG	10 U	12 U	12 U	12 U	11 U	13 U	11 U
TOLUENE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
trans-1,3-DICHLOROPROPENE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
1,1,2-TRICHLOROETHANE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
TETRACHLOROETHYLENE(PCE)	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
2-HEXANONE	UG/KG	10 U	12 U	12 U	12 U	11 U	13 U	11 U
DIBROMOCHLOROMETHANE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
CHLOROBENZENE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
ETHYLBENZENE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
XYLENES, TOTAL	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U

Analytical Data Summary
Volatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS050MW470	SS050MW471	SS050MW471	SS050MW472	SS050MW472	SS050MW473	SS050MW473
	Alias	MW12-3	MW12-18	MW12-18	MW12-16	MW12-16	MW12-17	MW12-17
	SampleID	SIA011	SIA016	SIA017	SIA003	SIA004	SIA005	SIA006
	Depth	20-22	6-8	22-24	0-2	18-20	0-2	18-20
Parameter								
STYRENE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
BROMOFORM	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U
1,1,2,2-TETRACHLOROETHANE	UG/KG	5 U	6 U	6 U	6 U	6 U	6 U	6 U

Analytical Summary
Semivolatile Organics In Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS025SB017	SS025SB017	SS025SB018	SS025SB018	SS025SB019	SS025SB019	SS025SB020
	Alias	SB12-1	SB12-1	SB12-2	SB12-2	SB12-3	SB12-3	SB12-4
	SampleID	SIB018	SIB019	SIB021	SIB022	SIB040	SIB041	SIB025
	Depth	0-2	20-22	2-4	10-12	2-4	28-28	2-4
Parameter								
PHENOL	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
bis(2-CHLOROETHYL) ETHER (2-CHLOROETHYL ETHER)	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
2-CHLOROPHENOL	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
1,3-DICHLOROBENZENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
1,4-DICHLOROBENZENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
1,2-DICHLOROBENZENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
2-METHYLPHENOL (o-CRESOL)	UG/KG	440 U	340 U	430 U	380 U	430 UJ	390 UJ	420 U
2,2'-OXYBIS(1-CHLORO)PROPANE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
4-METHYLPHENOL (p-CRESOL)	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
N-NITROSODI-n-PROPYLAMINE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
HEXACHLOROETHANE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
NITROBENZENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
ISOPHORONE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
2-NITROPHENOL	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
2,4-DIMETHYLPHENOL	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
bis(2-CHLOROETHOXY) METHANE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
2,4-DICHLOROPHENOL	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
1,2,4-TRICHLOROBENZENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
NAPHTHALENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
4-CHLOROANILINE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
HEXACHLOROBUTADIENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
4-CHLORO-3-METHYLPHENOL	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
2-METHYLNAPHTHALENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
HEXACHLOROCYCLOPENTADIENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
2,4,6-TRICHLOROPHENOL	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
2,4,5-TRICHLOROPHENOL	UG/KG	1100 U	860 U	1100 U	960 U	1100 U	990 U	1100 U
2-CHLORONAPHTHALENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
2-NITROANILINE	UG/KG	1100 U	860 U	1100 U	960 U	1100 U	990 U	1100 U
DIMETHYL PHTHALATE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
2,6-DINITROTOLUENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U

Analytical Data Summary
Semivolatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS025SB017	SS025SB017	SS025SB018	SS025SB018	SS025SB019	SS025SB019	SS025SB020
	Alias	SB12-1	SB12-1	SB12-2	SB12-2	SB12-3	SB12-3	SB12-4
	SampleID	SIB018	SIB019	SIB021	SIB022	SIB040	SIB041	SIB025
	Depth	0-2	20-22	2-4	10-12	2-4	28-28	2-4
Parameter								
ACENAPHTHYLENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
3-NITROANILINE	UG/KG	1100 U	860 U	1100 U	960 U	1100 U	990 U	1100 U
ACENAPHTHENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
2,4-DINITROPHENOL	UG/KG	1100 U	860 U	1100 U	960 U	1100 U	990 U	1100 U
4-NITROPHENOL	UG/KG	1100 U	860 U	1100 U	960 U	1100 U	990 U	1100 U
DIBENZOFURAN	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
2,4-DINITROTOLUENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
DIETHYL PHTHALATE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
FLUORENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
4-CHLOROPHENYL PHENYL ETHER	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
4-NITROANILINE	UG/KG	1100 U	860 U	1100 U	960 U	1100 U	990 U	1100 U
4,6-DINITRO-2-METHYLPHENOL	UG/KG	1100 U	860 U	1100 U	960 U	1100 U	990 U	1100 U
N-NITROSODIPHENYLAMINE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
4-BROMOPHENYL PHENYL ETHER	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
HEXACHLOROBENZENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
PENTACHLOROPHENOL	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
PHENANTHRENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
ANTHRACENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
CARBAZOLE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
DI-n-BUTYL PHTHALATE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
FLUORANTHENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
PYRENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
BENZYL BUTYL PHTHALATE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
BENZO(a)ANTHRACENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
3,3'-DICHLOROBENZIDINE	UG/KG	440 U	340 U	430 UJ	380 UJ	430 UJ	390 UJ	420 U
CHRYSENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
bis(2-ETHYLHEXYL) PHTHALATE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
DI-n-OCTYLPHTHALATE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
BENZO(b)FLUORANTHENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
BENZO(k)FLUORANTHENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U

Analytical Data Summary
Semivolatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS025SB017	SS025SB017	SS025SB018	SS025SB018	SS025SB019	SS025SB019	SS025SB020
	Alias	SB12-1	SB12-1	SB12-2	SB12-2	SB12-3	SB12-3	SB12-4
	SampleID	SIB018	SIB019	SIB021	SIB022	SIB040	SIB041	SIB025
	Depth	0-2	20-22	2-4	10-12	2-4	28-28	2-4
Parameter								
BENZO(a)PYRENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
INDENO(1,2,3-c,d)PYRENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
DIBENZ(a,h)ANTHRACENE	UG/KG	440 U	340 U	430 U	380 U	430 U	390 U	420 U
BENZO(g,h,i)PERYLENE	UG/KG	440 U	340 U	430 U	380 U	430 U	380 U	420 U

Analytical Data Summary
Semivolatile Organics In Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

Parameter		StationID	SS025SB020	SS025SB021	SS025SB021	SS025SB022	SS025SB022	SS025SB023	SS025SB023
		Alias	SB12-4	SB12-5	SB12-5	SB12-6	SB12-6	SB12-7	SB12-7
		SampleID	SIB026	SIB027	SIB028	SIB029	SIB030	SIB009	SIB010FD1
		Depth	22-24	6-8	26-28	6-8	22-24	6-8	6-8
PHENOL	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
bis(2-CHLOROETHYL) ETHER (2-CHLOROETHYL ETHER)	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
2-CHLOROPHENOL	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
1,3-DICHLOROBENZENE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
1,4-DICHLOROBENZENE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
1,2-DICHLOROBENZENE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
2-METHYLPHENOL (o-CRESOL)	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
2,2'-OXYBIS(1-CHLORO)PROPANE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
4-METHYLPHENOL (p-CRESOL)	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
N-NITROSODI-n-PROPYLAMINE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
HEXACHLOROETHANE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
NITROBENZENE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
ISOPHORONE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
2-NITROPHENOL	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
2,4-DIMETHYLPHENOL	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
bis(2-CHLOROETHOXY) METHANE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
2,4-DICHLOROPHENOL	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
1,2,4-TRICHLOROBENZENE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
NAPHTHALENE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
4-CHLOROANILINE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
HEXACHLOROBUTADIENE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
4-CHLORO-3-METHYLPHENOL	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
2-METHYLNAPHTHALENE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
HEXACHLOROCYCLOPENTADIENE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
2,4,6-TRICHLOROPHENOL	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
2,4,5-TRICHLOROPHENOL	UG/KG		930 U	1100 U	990 U	1100 U	980 U	1000 U	1000 U
2-CHLORONAPHTHALENE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
2-NITROANILINE	UG/KG		930 U	1100 U	990 U	1100 U	980 U	1000 U	1000 U
DIMETHYL PHTHALATE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U
2,6-DINITROTOLUENE	UG/KG		370 U	430 U	390 U	430 U	390 U	410 U	410 U

Analytical [illegible] Summary
Semivolatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS025SB020	SS025SB021	SS025SB021	SS025SB022	SS025SB022	SS025SB023	SS025SB023
	Alias	SB12-4	SB12-5	SB12-5	SB12-6	SB12-6	SB12-7	SB12-7
	SampleID	SIB026	SIB027	SIB028	SIB029	SIB030	SIB009	SIB010FD1
	Depth	22-24	6-8	26-28	6-8	22-24	6-8	6-8
Parameter								
ACENAPHTHYLENE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
3-NITROANILINE	UG/KG	930 U	1100 U	990 U	1100 U	980 U	1000 U	1000 U
ACENAPHTHENE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
2,4-DINITROPHENOL	UG/KG	930 U	1100 U	990 U	1100 U	980 U	1000 U	1000 U
4-NITROPHENOL	UG/KG	930 U	1100 U	990 U	1100 U	980 U	1000 U	1000 U
DIBENZOFURAN	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
2,4-DINITROTOLUENE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
DIETHYL PHTHALATE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
FLUORENE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
4-CHLOROPHENYL PHENYL ETHER	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
4-NITROANILINE	UG/KG	930 U	1100 U	990 U	1100 U	980 U	1000 U	1000 U
4,6-DINITRO-2-METHYLPHENOL	UG/KG	930 U	1100 U	990 U	1100 U	980 U	1000 U	1000 U
N-NITROSODIPHENYLAMINE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
4-BROMOPHENYL PHENYL ETHER	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
HEXACHLOROBENZENE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
PENTACHLOROPHENOL	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
PHENANTHRENE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
ANTHRACENE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
CARBAZOLE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 UJ	410 UJ
DI-n-BUTYL PHTHALATE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
FLUORANTHENE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
PYRENE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
BENZYL BUTYL PHTHALATE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
BENZO(a)ANTHRACENE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
3,3'-DICHLOROBENZIDINE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
CHRYSENE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
bis(2-ETHYLHEXYL) PHTHALATE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
DI-n-OCTYLPHTHALATE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
BENZO(b)FLUORANTHENE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
BENZO(k)FLUORANTHENE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U

Analytical Data Summary
Semivolatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS025SB020	SS025SB021	SS025SB021	SS025SB022	SS025SB022	SS025SB023	SS025SB023
	Alias	SB12-4	SB12-5	SB12-5	SB12-6	SB12-6	SB12-7	SB12-7
	SampleID	SIB028	SIB027	SIB028	SIB029	SIB030	SIB009	SIB010FD1
	Depth	22-24	6-8	26-28	6-8	22-24	6-8	6-8
Parameter								
BENZO(e)PYRENE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
INDENO(1,2,3-c,d)PYRENE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
DIBENZ(a,h)ANTHRACENE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U
BENZO(g,h,i)PERYLENE	UG/KG	370 U	430 U	390 U	430 U	390 U	410 U	410 U

Analytical Data Summary
Semivolatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS025SB023	SS025SB024	SS025SB024	SS025SB025	SS025SB025	SS025SB026	SS025SB026
	Alias	SB12-7	SB12-8	SB12-8	SB12-9	SB12-9	SB12-10	SB12-10
	SampleID	SIB011	SIB004	SIB005	SIB008	SIB007	SIB042	SIB043
	Depth	22-24	4-6	20-22	4-6	20-22	6-8	12-14
Parameter								
PHENOL	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
bis(2-CHLOROETHYL) ETHER (2-CHLOROETHYL ETHER)	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
2-CHLOROPHENOL	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
1,3-DICHLOROBENZENE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
1,4-DICHLOROBENZENE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
1,2-DICHLOROBENZENE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
2-METHYLPHENOL (o-CRESOL)	UG/KG	360 U	430 U	380 U	450 U	380 U	430 UJ	380 UJ
2,2'-OXYBIS(1-CHLORO)PROPANE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
4-METHYLPHENOL (p-CRESOL)	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
N-NITROSODI-n-PROPYLAMINE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
HEXACHLOROETHANE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
NITROBENZENE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
ISOPHORONE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
2-NITROPHENOL	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
2,4-DIMETHYLPHENOL	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
bis(2-CHLOROETHOXY) METHANE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
2,4-DICHLOROPHENOL	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
1,2,4-TRICHLOROBENZENE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
NAPHTHALENE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
4-CHLOROANILINE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
HEXACHLOROBUTADIENE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
4-CHLORO-3-METHYLPHENOL	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
2-METHYLNAPHTHALENE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
HEXACHLOROCYCLOPENTADIENE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
2,4,6-TRICHLOROPHENOL	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
2,4,5-TRICHLOROPHENOL	UG/KG	910 U	1100 U	940 U	1100 U	960 U	1100 U	960 U
2-CHLORONAPHTHALENE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
2-NITROANILINE	UG/KG	910 U	1100 U	940 U	1100 U	960 U	1100 U	960 U
DIMETHYL PHTHALATE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
2,6-DINITROTOLUENE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U

Analytical Data Summary
Semivolatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

Parameter		StationID	SS025SB023	SS025SB024	SS025SB024	SS025SB025	SS025SB025	SS025SB026	SS025SB026
		Alias	SB12-7	SB12-8	SB12-8	SB12-9	SB12-9	SB12-10	SB12-10
		SampleID	SIB011	SIB004	SIB005	SIB006	SIB007	SIB042	SIB043
		Depth	22-24	4-6	20-22	4-6	20-22	8-8	12-14
ACENAPHTHYLENE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
3-NITROANILINE	UG/KG		910 U	1100 U	940 U	1100 U	960 U	1100 U	960 U
ACENAPHTHENE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
2,4-DINITROPHENOL	UG/KG		910 U	1100 U	940 U	1100 U	960 U	1100 U	960 U
4-NITROPHENOL	UG/KG		910 U	1100 U	940 U	1100 U	960 U	1100 U	960 U
DIBENZOFURAN	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
2,4-DINITROTOLUENE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
DIETHYL PHTHALATE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
FLUORENE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
4-CHLOROPHENYL PHENYL ETHER	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
4-NITROANILINE	UG/KG		910 U	1100 U	940 U	1100 U	960 U	1100 U	960 U
4,6-DINITRO-2-METHYLPHENOL	UG/KG		910 U	1100 U	940 U	1100 U	960 U	1100 U	960 U
N-NITROSODIPHENYLAMINE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
4-BROMOPHENYL PHENYL ETHER	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
HEXACHLOROBENZENE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
PENTACHLOROPHENOL	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
PHENANTHRENE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
ANTHRACENE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
CARBAZOLE	UG/KG		360 UJ	430 U	380 U	450 U	380 U	430 U	380 U
DI-n-BUTYL PHTHALATE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
FLUORANTHENE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
PYRENE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
BENZYL BUTYL PHTHALATE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
BENZO(a)ANTHRACENE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
3,3'-DICHLOROBENZIDINE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 UJ	380 UJ
CHRYSENE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
bis(2-ETHYLHEXYL) PHTHALATE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
DI-n-OCTYLPHTHALATE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
BENZO(b)FLUORANTHENE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U
BENZO(k)FLUORANTHENE	UG/KG		360 U	430 U	380 U	450 U	380 U	430 U	380 U

Analytical [illegible] Summary
Semivolatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS025SB023	SS025SB024	SS025SB024	SS025SB025	SS025SB025	SS025SB026	SS025SB026
	Alias	SB12-7	SB12-8	SB12-8	SB12-9	SB12-9	SB12-10	SB12-10
	SampleID	SIB011	SIB004	SIB005	SIB006	SIB007	SIB042	SIB043
	Depth	22-24	4-6	20-22	4-6	20-22	6-8	12-14
Parameter								
BENZO(a)PYRENE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
INDENO(1,2,3-c,d)PYRENE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
DIBENZ(a,h)ANTHRACENE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U
BENZO(g,h,i)PERYLENE	UG/KG	360 U	430 U	380 U	450 U	380 U	430 U	380 U

Analytical Data Summary
Semivolatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

Parameter		StationID	SS025SB027	SS025SB027	SS025SB027	SS025SB027	SS025SB028	SS025SB028	SS045SB017
		Alias	SB12-14	SB12-14	SB12-14	SB12-14	SB12-15	SB12-15	SB12-11
		SampleID	SIB014	SIB014LR1	SIB015	SIB015LR1	SIB012	SIB013	SIB032
		Depth	14-16	14-16	26-28	26-28	6-8	20-22	2-4
PHENOL	UG/KG		410 U		380 U		400 U	440 U	420 U
bis(2-CHLOROETHYL) ETHER (2-CHLOROETHYL ETHER)	UG/KG		410 U		380 U		400 U	440 U	420 U
2-CHLOROPHENOL	UG/KG		410 U		380 U		400 U	440 U	420 U
1,3-DICHLOROBENZENE	UG/KG		410 U		380 U		400 U	440 U	420 U
1,4-DICHLOROBENZENE	UG/KG		410 U		380 U		400 U	440 U	420 U
1,2-DICHLOROBENZENE	UG/KG		410 U		380 U		400 U	440 U	420 U
2-METHYLPHENOL (o-CRESOL)	UG/KG		410 U		380 U		400 U	440 U	420 U
2,2'-OXYBIS(1-CHLORO)PROPANE	UG/KG		410 U		380 U		400 U	440 U	420 U
4-METHYLPHENOL (p-CRESOL)	UG/KG		410 U		380 U		400 U	440 U	420 U
N-NITROSODI-n-PROPYLAMINE	UG/KG		410 U		380 U		400 U	440 U	420 U
HEXACHLOROETHANE	UG/KG		410 U		380 U		400 U	440 U	420 U
NITROBENZENE	UG/KG		410 U		380 U		400 U	440 U	420 U
ISOPHORONE	UG/KG		410 U		380 U		400 U	440 U	420 U
2-NITROPHENOL	UG/KG		410 U		380 U		400 U	440 U	420 U
2,4-DIMETHYLPHENOL	UG/KG		410 U		380 U		400 U	440 U	420 U
bis(2-CHLOROETHOXY) METHANE	UG/KG		410 U		380 U		400 U	440 U	420 U
2,4-DICHLOROPHENOL	UG/KG		410 U		380 U		400 U	440 U	420 U
1,2,4-TRICHLOROBENZENE	UG/KG		410 U		380 U		400 U	440 U	420 U
NAPHTHALENE	UG/KG			15000 -		5500 -	400 U	440 U	420 U
4-CHLOROANILINE	UG/KG		410 U		380 U		400 U	440 U	420 U
HEXACHLOROBUTADIENE	UG/KG		410 U		380 U		400 U	440 U	420 U
4-CHLORO-3-METHYLPHENOL	UG/KG		410 U		380 U		400 U	440 U	420 U
2-METHYLNAPHTHALENE	UG/KG		910 -		990 -		400 U	440 U	420 U
HEXACHLOROCYCLOPENTADIENE	UG/KG		410 U		380 U		400 U	440 U	420 UJ
2,4,6-TRICHLOROPHENOL	UG/KG		410 U		380 U		400 U	440 U	420 U
2,4,5-TRICHLOROPHENOL	UG/KG		1000 U		950 U		1000 U	1100 U	1000 U
2-CHLORONAPHTHALENE	UG/KG		410 U		380 U		400 U	440 U	420 U
2-NITROANILINE	UG/KG		1000 U		950 U		1000 U	1100 U	1000 U
DIMETHYL PHTHALATE	UG/KG		410 U		380 U		400 U	440 U	420 U
2,6-DINITROTOLUENE	UG/KG		410 U		380 U		400 U	440 U	420 U

Analytical Summary
Semivolatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS025SB027	SS025SB027	SS025SB027	SS025SB027	SS025SB028	SS025SB028	SS045SB017
	Alias	SB12-14	SB12-14	SB12-14	SB12-14	SB12-15	SB12-15	SB12-11
	SampleID	SIB014	SIB014LR1	SIB015	SIB015LR1	SIB012	SIB013	SIB032
	Depth	14-16	14-16	26-28	26-28	8-8	20-22	2-4
Parameter								
ACENAPHTHYLENE	UG/KG	410 U		380 U		400 U	440 U	420 U
3-NITROANILINE	UG/KG	1000 U		950 U		1000 U	1100 U	1000 U
ACENAPHTHENE	UG/KG	410 U		380 U		400 U	440 U	420 U
2,4-DINITROPHENOL	UG/KG	1000 U		950 U		1000 U	1100 U	1000 UJ
4-NITROPHENOL	UG/KG	1000 U		950 U		1000 U	1100 U	1000 U
DIBENZOFURAN	UG/KG	410 U		380 U		400 U	440 U	420 U
2,4-DINITROTOLUENE	UG/KG	410 U		380 U		400 U	440 U	420 U
DIETHYL PHTHALATE	UG/KG	410 U		380 U		400 U	440 U	420 U
FLUORENE	UG/KG	410 U		380 U		400 U	440 U	420 U
4-CHLOROPHENYL PHENYL ETHER	UG/KG	410 U		380 U		400 U	440 U	420 U
4-NITROANILINE	UG/KG	1000 U		950 U		1000 U	1100 U	1000 U
4,6-DINITRO-2-METHYLPHENOL	UG/KG	1000 U		950 U		1000 U	1100 U	1000 U
N-NITROSODIPHENYLAMINE	UG/KG	410 U		380 U		400 U	440 U	420 U
4-BROMOPHENYL PHENYL ETHER	UG/KG	410 U		380 U		400 U	440 U	420 U
HEXACHLOROBENZENE	UG/KG	410 U		380 U		400 U	440 U	420 U
PENTACHLOROPHENOL	UG/KG	410 U		380 U		400 U	440 U	420 U
PHENANTHRENE	UG/KG	410 U		380 U		400 U	440 U	420 U
ANTHRACENE	UG/KG	410 U		380 U		400 U	440 U	420 U
CARBAZOLE	UG/KG	410 UJ		380 UJ		400 UJ	440 UJ	420 UJ
DI-n-BUTYL PHTHALATE	UG/KG	410 U		380 U		400 U	440 U	420 U
FLUORANTHENE	UG/KG	410 U		380 U		400 U	440 U	420 U
PYRENE	UG/KG	410 U		380 U		400 U	440 U	420 U
BENZYL BUTYL PHTHALATE	UG/KG	410 U		380 U		400 U	440 U	420 U
BENZO(a)ANTHRACENE	UG/KG	410 U		380 U		400 U	440 U	420 U
3,3'-DICHLOROBENZIDINE	UG/KG	410 U		380 U		400 U	440 U	420 UJ
CHRYSENE	UG/KG	410 U		380 U		400 U	440 U	420 U
bis(2-ETHYLHEXYL) PHTHALATE	UG/KG	410 U		380 U		400 U	440 U	420 U
DI-n-OCTYLPHTHALATE	UG/KG	410 U		380 U		400 U	440 U	420 U
BENZO(b)FLUORANTHENE	UG/KG	410 U		380 U		400 U	440 U	420 U
BENZO(k)FLUORANTHENE	UG/KG	410 U		380 U		400 U	440 U	420 U

Analytical Data Summary
Semivolatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS025SB027	SS025SB027	SS025SB027	SS025SB027	SS025SB028	SS025SB028	SS045SB017
	Alias	SB12-14	SB12-14	SB12-14	SB12-14	SB12-15	SB12-15	SB12-11
	SampleID	SIB014	SIB014LR1	SIB015	SIB015LR1	SIB012	SIB013	SIB032
	Depth	14-16	14-16	26-28	26-28	6-8	20-22	2-4
Parameter								
BENZO(a)PYRENE	UG/KG	410 U		380 U		400 U	440 U	420 U
INDENO(1,2,3-c,d)PYRENE	UG/KG	410 U		380 U		400 U	440 U	420 U
DIBENZ(a,h)ANTHRACENE	UG/KG	410 U		380 U		400 U	440 U	420 U
BENZO(g,h,i)PERYLENE	UG/KG	410 U		380 U		400 U	440 U	420 U

Analytical Summary
Semivolatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

Parameter	StationID	SS045SB017	SS045SB017	SS045SB018	SS045SB018	SS045SB019	SS045SB019
	Alias	SB12-11	SB12-11	SB12-12	SB12-12	SB12-13	SB12-13
	SampleID	SIB033FD1	SIB034	SIB035	SIB036	SIB037	SIB038
	Depth	2-4	20-21	0-2	20-22	4-6	18-20
PHENOL	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
bis(2-CHLOROETHYL) ETHER (2-CHLOROETHYL ETHER)	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
2-CHLOROPHENOL	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
1,3-DICHLOROBENZENE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
1,4-DICHLOROBENZENE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
1,2-DICHLOROBENZENE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
2-METHYLPHENOL (o-CRESOL)	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
2,2'-OXYBIS(1-CHLORO)PROPANE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
4-METHYLPHENOL (p-CRESOL)	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
N-NITROSODI-n-PROPYLAMINE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
HEXACHLOROETHANE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
NITROBENZENE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
ISOPHORONE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
2-NITROPHENOL	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
2,4-DIMETHYLPHENOL	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
bis(2-CHLOROETHOXY) METHANE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
2,4-DICHLOROPHENOL	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
1,2,4-TRICHLOROBENZENE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
NAPHTHALENE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	460 -
4-CHLOROANILINE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
HEXACHLOROBUTADIENE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
4-CHLORO-3-METHYLPHENOL	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
2-METHYLNAPHTHALENE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	500 -
HEXACHLOROCYCLOPENTADIENE	UG/KG	420 UJ	360 UJ	360 UJ	380 UJ	380 UJ	380 UJ
2,4,6-TRICHLOROPHENOL	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
2,4,5-TRICHLOROPHENOL	UG/KG	1000 U	900 U	900 UJ	950 U	940 U	940 U
2-CHLORONAPHTHALENE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
2-NITROANILINE	UG/KG	1000 U	900 U	900 UJ	950 U	940 U	940 U
DIMETHYL PHTHALATE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
2,6-DINITROTOLUENE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U

Analytical Data Summary
Semivolatile Organics In Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

Parameter		StationID	SS045SB017	SS045SB017	SS045SB018	SS045SB018	SS045SB019	SS045SB019
		Alias	SB12-11	SB12-11	SB12-12	SB12-12	SB12-13	SB12-13
		SampleID	SIB033FD1	SIB034	SIB035	SIB036	SIB037	SIB038
		Depth	2-4	20-21	0-2	20-22	4-6	18-20
ACENAPHTHYLENE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
3-NITROANILINE	UG/KG		1000 U	900 U	900 UJ	950 U	940 U	940 U
ACENAPHTHENE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
2,4-DINITROPHENOL	UG/KG		1000 UJ	900 UJ	900 UJ	950 UJ	940 UJ	940 UJ
4-NITROPHENOL	UG/KG		1000 U	900 U	900 UJ	950 U	940 U	940 U
DIBENZOFURAN	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
2,4-DINITROTOLUENE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
DIETHYL PHTHALATE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
FLUORENE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
4-CHLOROPHENYL PHENYL ETHER	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
4-NITROANILINE	UG/KG		1000 U	900 U	900 UJ	950 U	940 U	940 U
4,6-DINITRO-2-METHYLPHENOL	UG/KG		1000 U	900 U	900 UJ	950 U	940 U	940 U
N-NITROSODIPHENYLAMINE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
4-BROMOPHENYL PHENYL ETHER	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
HEXACHLOROBENZENE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
PENTACHLOROPHENOL	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
PHENANTHRENE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
ANTHRACENE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
CARBAZOLE	UG/KG		420 UJ	360 UJ	360 UJ	380 UJ	380 UJ	380 UJ
DI-n-BUTYL PHTHALATE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
FLUORANTHENE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
PYRENE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
BENZYL BUTYL PHTHALATE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
BENZO(a)ANTHRACENE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
3,3'-DICHLOROBENZIDINE	UG/KG		420 UJ	360 UJ	360 UJ	380 UJ	380 UJ	380 UJ
CHRYSENE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
bis(2-ETHYLHEXYL) PHTHALATE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
DI-n-OCTYLPHTHALATE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
BENZO(b)FLUORANTHENE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U
BENZO(k)FLUORANTHENE	UG/KG		420 U	360 U	360 UJ	380 U	380 U	380 U

Analytical [illegible] Summary
Semivolatile Organics in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS045SB017	SS045SB017	SS045SB018	SS045SB018	SS045SB019	SS045SB019
	Alias	SB12-11	SB12-11	SB12-12	SB12-12	SB12-13	SB12-13
	SampleID	SIB033FD1	SIB034	SIB035	SIB036	SIB037	SIB038
	Depth	2-4	20-21	0-2	20-22	4-6	18-20
Parameter							
BENZO(a)PYRENE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
INDENO(1,2,3-c,d)PYRENE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
DIBENZ(a,h)ANTHRACENE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U
BENZO(g,h,i)PERYLENE	UG/KG	420 U	360 U	360 UJ	380 U	380 U	380 U

Analytical Data Summary
Total Metals in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS025SB017	SS025SB017	SS025SB018	SS025SB018	SS025SB019	SS025SB019	SS025SB020	SS025SB020	SS025SB021
	Alias	SB12-1	SB12-1	SB12-2	SB12-2	SB12-3	SB12-3	SB12-4	SB12-4	SB12-5
	SampleID	SIB018	SIB019	SIB021	SIB022	SIB040	SIB041	SIB025	SIB026	SIB027
	Depth	0-2	20-22	2-4	10-12	2-4	26-28	2-4	22-24	6-8
Parameter										
ANTIMONY	MG/KG	0.53 UJ	0.42 UJ	0.53 UJ	0.47 UJ	0.53 UJ	0.48 UJ	0.51 UJ	0.45 UJ	0.52 UJ
ARSENIC	MG/KG	4.8 J	4.9 J	6.8 J	4.7 J	7.1 J	5.3 J	8.1 J	5.2 J	4.3 J
BARIUM	MG/KG	154 -	31.2 -	169 -	58.2 -	139 -	21.8 -	139 -	31.8 -	143 -
BERYLLIUM	MG/KG	1.5 -	0.38 J	1.8 -	0.87 -	1.1 -	0.4 J	1.2 -	0.55 -	1.1 -
CADMIUM	MG/KG	0.68 J	0.3 J	0.68 J	0.48 J	0.34 J	0.29 U	0.31 U	0.32 J	0.31 J
CHROMIUM, TOTAL	MG/KG	25.3 -	8.4 -	29.2 -	14 -	15.4 -	15 -	14.7 J	9.4 J	10.7 J
COBALT	MG/KG	10.4 -	2 J	12.7 -	5.6 -	8.3 -	2 J	9.1 -	3.2 -	4.8 -
COPPER	MG/KG	14.4 -	4 -	14.2 -	7.9 -	11.3 -	2.9 -	15.8 J	6.3 J	8.9 J
IRON	MG/KG	19500 J	5960 J	21800 J	11800 J	12200 J	7820 J	11800 -	8230 -	8510 -
LEAD	MG/KG	17.6 -	5.9 -	17.9 -	11.5 -	19.8 -	8.1 -	16.4 -	6.8 -	16.6 -
MANGANESE	MG/KG	703 J	250 J	628 J	275 J	419 J	58.9 J	495 -	275 -	282 -
MERCURY	MG/KG	0.07 U	0.05 U	0.07 U	0.07 U	0.07 U	0.06 U	0.08 U	0.06 U	0.07 U
NICKEL	MG/KG	21.1 -	5.5 -	22.8 -	12.1 -	13.7 -	11.7 -	20.6 -	7.1 -	11.4 -
SELENIUM	MG/KG	2 UJ	1.6 UJ	2 UJ	1.7 UJ	2 U	1.8 U	1.9 U	1.7 U	2 U
SILVER	MG/KG	0.67 U	0.52 U	0.66 U	0.58 U	0.66 U	0.6 U	0.64 U	0.56 U	0.65 U
THALLIUM	MG/KG	0.34 U	0.21 U	0.3 J	0.23 U	0.38 J	0.24 U	0.32 J	0.22 U	0.26 U
VANADIUM	MG/KG	38.4 -	21.4 -	47.9 -	23.7 -	32.4 J	18.4 J	30.3 J	21.8 J	29.2 J
ZINC	MG/KG	48.7 -	14.9 -	52.4 -	30.9 -	31.8 -	37.9 -	31.4 J	22.3 J	22.3 J

Analytical Data Summary
Total Metals in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS025SB021	SS025SB022	SS025SB022	SS025SB023	SS025SB023	SS025SB023	SS025SB024	SS025SB024	SS025SB025
	Alias	SB12-5	SB12-6	SB12-6	SB12-7	SB12-7	SB12-7	SB12-8	SB12-8	SB12-9
	SampleID	SIB028	SIB029	SIB030	SIB009	SIB010FD1	SIB011	SIB004	SIB005	SIB006
	Depth	26-28	6-8	22-24	6-8	6-8	22-24	4-6	20-22	4-6
Parameter										
ANTIMONY	MG/KG	0.48 UJ	0.52 UJ	0.47 UJ	0.49 R	0.49 R	0.44 R	0.52 R	0.46 R	0.55 R
ARSENIC	MG/KG	2.4 J	4.8 J	4.5 J	9.4 J	6.3 J	8.8 J	7.6 J	6.8 J	7.9 J
BARIUM	MG/KG	47.7 -	91.7 -	93.1 -	48.9 -	161 -	130 -	138 -	36 -	321 -
BERYLLIUM	MG/KG	0.8 -	1.3 -	0.72 -	0.88 -	1.3 -	0.44 -	1 -	0.38 J	1.2 -
CADMIUM	MG/KG	0.35 J	0.33 J	0.28 U	0.4 J	0.76 J	0.43 J	0.52 J	0.42 J	0.49 J
CHROMIUM, TOTAL	MG/KG	17.3 J	18.9 J	9 J	9.8 J	23.1 J	12.3 J	12.4 J	6 J	15.7 J
COBALT	MG/KG	5.1 -	8.6 -	6.3 -	5.6 -	8 -	4.7 -	8 -	2.4 -	8.9 -
COPPER	MG/KG	6.7 J	11.6 J	8.8 J	6.8 J	11.8 J	6 J	10 J	4.4 J	10.6 J
IRON	MG/KG	13100 -	16400 -	10200 -	7460 J	19000 J	13900 J	8770 J	5170 J	12500 J
LEAD	MG/KG	9 -	14.2 -	10.8 -	14.5 -	15.5 -	5.5 -	18.5 -	6.7 -	14.1 -
MANGANESE	MG/KG	164 -	538 -	404 -	312 -	444 -	741 -	391 -	182 -	335 -
MERCURY	MG/KG	0.06 U	0.07 U	0.06 U	0.06 U	0.06 U	0.06 U	0.07 U	0.06 U	0.07 U
NICKEL	MG/KG	7.8 -	16.7 -	11.9 -	10.9 -	16.9 -	15.5 -	12.5 -	4.7 -	14.6 -
SELENIUM	MG/KG	1.6 U	2 U	1.8 U	3.7 U	3.7 U	3.3 U	3.9 U	3.4 U	4.1 U
SILVER	MG/KG	0.6 U	0.65 U	0.59 U	0.62 U	0.62 U	0.55 U	0.65 U	0.57 U	0.68 U
THALLIUM	MG/KG	0.24 U	0.28 U	0.24 U	1.2 U	1.2 U	1.1 U	1.3 U	1.1 U	1.4 U
VANADIUM	MG/KG	18.6 J	35.3 J	24.6 J	21.9 -	36.8 -	34 -	24.7 -	16 -	21.9 -
ZINC	MG/KG	39.7 J	40.3 J	21.3 J	17.8 J	46 J	23.5 J	24.3 J	12.8 J	30.9 J

Analytical Data Summary
Total Metals in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS025SB025	SS025SB026	SS025SB026	SS025SB027	SS025SB027	SS025SB028	SS025SB028	SS045SB017	SS045SB017
	Alias	SB12-9	SB12-10	SB12-10	SB12-14	SB12-14	SB12-15	SB12-15	SB12-11	SB12-11
	SampleID	SIB007	SIB042	SIB043	SIB014	SIB015	SIB012	SIB013	SIB032	SIB033FD1
	Depth	20-22	6-8	12-14	14-16	26-28	6-8	20-22	2-4	2-4
Parameter										
ANTIMONY	MG/KG	0.46 R	0.53 UJ	0.47 UJ	0.49 R	0.48 R	0.49 R	0.53 R	0.5 UJ	0.51 UJ
ARSENIC	MG/KG	4.2 J	4.6 J	4.7 J	7.3 J	7 J	6.6 J	5.5 J	3.5 J	5.8 J
BARIUM	MG/KG	38.4 -	125 -	38 -	79.5 -	59.2 -	124 -	38.3 -	140 -	120 -
BERYLLIUM	MG/KG	0.56 -	1.3 -	0.68 -	0.86 -	0.72 -	1.3 -	0.36 J	0.95 -	1 -
CADMIUM	MG/KG	0.44 J	0.32 U	0.33 J	0.63 J	0.49 J	0.87 J	0.32 U	0.36 J	0.35 J
CHROMIUM, TOTAL	MG/KG	8.9 J	17.7 -	10.1 -	18.6 J	13 J	23.9 J	8.4 J	12.2 -	15 -
COBALT	MG/KG	3 -	7.7 -	3.2 -	5.3 -	4.8 -	8.1 -	2.9 -	6.2 -	8.7 -
COPPER	MG/KG	5 J	11.5 -	7.4 -	9.5 J	8.4 J	11.1 J	4.2 J	8.9 -	9.2 -
IRON	MG/KG	6830 J	13800 J	9390 J	14200 J	11600 J	19800 J	6280 J	10100 J	12600 J
LEAD	MG/KG	8.6 -	14.9 -	9.5 -	13.4 -	12 -	13.6 -	5.9 J	14 -	15.2 -
MANGANESE	MG/KG	140 -	478 J	170 J	337 -	338 -	444 -	222 -	323 J	568 J
MERCURY	MG/KG	0.06 U	0.07 U	0.06 U	0.06 U	0.06 U	0.06 U	0.07 U	0.06 U	0.06 U
NICKEL	MG/KG	6.2 -	16.2 -	9.3 -	12 -	10.8 -	17.6 -	6 -	11.9 -	14.7 -
SELENIUM	MG/KG	3.5 U	2 U	1.8 U	3.7 U	3.5 U	3.7 U	4 U	1.9 U	1.9 U
SILVER	MG/KG	0.56 U	0.66 U	0.58 U	0.62 U	0.58 U	0.61 U	0.67 U	0.63 U	0.63 U
THALLIUM	MG/KG	1.2 U	0.26 U	0.23 U	1.2 U	1.2 U	1.2 U	1.3 U	0.25 U	0.25 U
VANADIUM	MG/KG	10 -	25.1 J	21.7 J	33.6 -	21.4 -	39 -	16.8 -	28.8 J	31.4 J
ZINC	MG/KG	34.4 J	36.3 -	23.4 -	38.7 J	30 J	48.4 J	15.5 J	24.1 -	29.5 -

Analytical Data Summary
Total Metals in Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS045SB017	SS045SB018	SS045SB018	SS045SB019	SS045SB019	SS050MW468	SS050MW468	SS050MW469	SS050MW469
	Alias	SB12-11	SB12-12	SB12-12	SB12-13	SB12-13	MW12-1	MW12-1	MW12-2	MW12-2
	SampleID	SIB034	SIB035	SIB036	SIB037	SIB038	SIA042	SIA043	SIA025	SIA026FD1
	Depth	20-21	0-2	20-22	4-6	18-20	2-4	26-26	6-8	6-8
Parameter										
ANTIMONY	MG/KG	0.44 UJ	0.52 J	0.46 UJ	0.46 UJ	0.45 UJ	0.54 UJ	0.45 UJ	0.46 U	0.47 U
ARSENIC	MG/KG	5.3 J	2.1 J	7.1 J	3.4 J	4.3 J	8.7 J	6.4 J	4.1 J	4.9 J
BARIUM	MG/KG	43.1 -	67.5 -	59.6 -	45.9 -	80.6 -	129 -	31.2 -	38.4 J	141 J
BERYLLIUM	MG/KG	0.3 J	0.38 J	0.59 -	0.5 -	0.47 -	1 -	0.38 J	0.8 -	0.94 -
CADMIUM	MG/KG	0.26 U	1.1 -	0.29 J	0.33 J	0.39 J	0.42 J	0.49 J	0.4 J	0.55 J
CHROMIUM, TOTAL	MG/KG	5.9 -	12.1 -	9.7 -	7.1 -	22.3 -	15.7 -	5.3 -	10.6 -	12 -
COBALT	MG/KG	2.5 -	5.6 -	4.2 -	3 -	4.4 -	7.4 -	2.4 -	4.9 -	6.6 -
COPPER	MG/KG	4.1 -	14.2 -	6.4 -	5.3 -	7.8 -	11.6 -	4.1 -	6.6 -	8.1 -
IRON	MG/KG	5500 J	5240 J	8580 J	5800 J	11300 J	11900 J	5120 J	9490 J	11200 J
LEAD	MG/KG	5.9 -	102 -	9.2 -	8.8 -	6.1 -	20.4 -	5.8 -	10.6 -	10.8 -
MANGANESE	MG/KG	273 J	284 J	292 J	203 J	823 J	433 J	201 J	261 -	338 -
MERCURY	MG/KG	0.06 U	0.05 U	0.06 U	0.06 U	0.06 U	0.11 J	0.06 U	0.06 U	0.06 U
NICKEL	MG/KG	7 -	16.1 -	9.9 -	7.2 -	23.8 -	13.9 -	5.8 -	10 -	12.5 -
SELENIUM	MG/KG	1.6 U	1.6 U	1.7 U	1.7 U	1.7 U	2 U	1.7 U	1.7 U	1.7 U
SILVER	MG/KG	0.55 U	2.5 -	0.58 U	0.57 U	0.57 U	0.67 U	0.56 U	0.58 U	0.58 U
THALLIUM	MG/KG	0.22 U	0.22 U	0.23 U	0.23 U	0.23 U	0.27 U	0.22 U	0.23 UJ	0.23 UJ
VANADIUM	MG/KG	20.1 J	13.2 J	21.1 J	15.7 J	35.1 J	29 J	15.8 J	28.2 -	30.4 -
ZINC	MG/KG	11.8 -	49.1 -	22.1 -	16.9 -	20.7 -	38.6 -	13.1 -	22.1 -	26 -

Analytical Data Summary
Total Metals In Soil
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS050MW469	SS050MW470	SS050MW470	SS050MW471	SS050MW471	SS050MW472	SS050MW472	SS050MW473	SS050MW473
	Alias	MW12-2	MW12-3	MW12-3	MW12-18	MW12-18	MW12-16	MW12-18	MW12-17	MW12-17
	SampleID	SIA027	SIA010	SIA011	SIA018	SIA017	SIA003	SIA004	SIA005	SIA006
	Depth	22-24	6-8	20-22	6-8	22-24	0-2	18-20	0-2	18-20
Parameter										
ANTIMONY	MG/KG	0.47 U	0.64 J	0.42 U	0.61 J	0.47 U	1.4 J	0.54 J	0.51 UJ	0.45 UJ
ARSENIC	MG/KG	6.8 J	7 J	6.5 J	7.7 J	2.8 J	5.5 J	10.8 J	5.9 J	15.8 J
BARIUM	MG/KG	86.4 J	208 J	35.2 J	141 J	51.9 J	185 J	51.1 J	105 J	115 J
BERYLLIUM	MG/KG	0.89 -	1.4 -	0.27 J	1.2 -	0.69 -	0.78 -	0.42 J	1.2 -	0.54 -
CADMIUM	MG/KG	0.48 J	0.64 J	0.25 J	0.73 J	0.49 J	2.4 -	0.54 J	0.63 J	0.54 J
CHROMIUM, TOTAL	MG/KG	12.5 -	21.3 -	6.9 -	20.7 -	12.7 -	25.7 J	10.9 J	23.3 J	19.5 J
COBALT	MG/KG	6.1 -	7.6 -	2.1 J	9.2 -	3 -	5.7 -	3.9 -	8.3 -	7.2 -
COPPER	MG/KG	9.2 -	12.7 -	3.8 -	10.9 -	5.7 -	18.5 J	8.3 J	14.3 J	10 J
IRON	MG/KG	12300 J	17800 J	5820 J	17400 J	10800 J	13900 J	14800 J	18400 J	15800 J
LEAD	MG/KG	9.4 -	14 -	3.3 J	14.5 -	7.9 -	606 -	5.7 -	14.8 -	6.4 -
MANGANESE	MG/KG	478 -	402 -	389 -	721 -	139 -	318 -	410 -	398 -	605 -
MERCURY	MG/KG	0.06 U	0.06 U	0.05 U	0.06 U	0.06 U	0.11 J	0.06 U	0.06 U	0.06 U
NICKEL	MG/KG	14.2 -	16.9 -	6.7 -	17.8 -	7.2 -	14.7 -	11.8 -	24.2 -	21.1 -
SELENIUM	MG/KG	1.8 U	1.8 U	1.8 U	1.8 U	1.8 U	3.7 U	3.4 U	3.8 U	3.4 U
SILVER	MG/KG	0.59 U	0.6 U	0.52 U	0.6 U	0.59 U	0.62 U	0.56 U	1.3 J	0.58 U
THALLIUM	MG/KG	0.23 UJ	0.31 J	0.21 UJ	0.32 J	0.24 UJ	1.2 U	1.1 U	1.3 U	1.1 U
VANADIUM	MG/KG	26.2 -	40.3 -	25.5 -	42.7 -	16.2 -	27.9 -	42.5 -	38.2 -	61.5 -
ZINC	MG/KG	30.7 -	42.6 -	11.1 -	43 -	29.9 -	92.7 J	23.8 J	47.2 J	25.3 J

Analytical L . Summary
Volatile Organics in Groundwater
Zone 5 RI Supplemental Sampling 1998
Kelly AFB

	StationID	SS050MW334	SS050MW334	SS050MW335	SS050MW336	SS050MW337	SS050MW338	SS050MW338
	Alias	MW12-4	MW12-4	MW12-5	MW12-6	MW12-7	MW12-8	MW12-8
	SampleID	SIA013	SIA014FD1	SIA019	SIA022	SIA032	SIA035	SIA035LR1
	Depth	0-0	0-0	0-0	0-0	0-0	0-0	0-0
Parameter								
CHLOROMETHANE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
VINYL CHLORIDE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
BROMOMETHANE	UG/L	1 U	1 U	1 U	1 U	1 UJ	1 UJ	
CHLOROETHANE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
1,1-DICHLOROETHENE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
ACETONE	UG/L	5 U	5 U	5 U	5 U	5 UJ	5 U	
CARBON DISULFIDE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
METHYLENE CHLORIDE	UG/L	2 U	2 U	2 U	2 U	2 U	2 U	
1,1-DICHLOROETHANE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
VINYL ACETATE	UG/L	5 U	5 U	5 U	5 U	5 U	5 U	
TOTAL 1,2-DICHLOROETHENE	UG/L	1 U	1 U	1 U	1 U	1 U	1 -	
METHYL ETHYL KETONE (2-BUTANONE)	UG/L	5 U	5 U	5 U	5 U	5 UJ	5 U	
CHLOROFORM	UG/L	1 U	1 U	1 -	1 U	1 U	1 U	
1,1,1-TRICHLOROETHANE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
CARBON TETRACHLORIDE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
BENZENE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
1,2-DICHLOROETHANE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
TRICHLOROETHYLENE (TCE)	UG/L	2 -	2 -	1 U	1 U	5 -	4 -	
1,2-DICHLOROPROPANE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
BROMODICHLOROMETHANE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
cis-1,3-DICHLOROPROPENE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
METHYL ISOBUTYL KETONE (4-METHYL-2-PENTANONE)	UG/L	5 UJ	5 UJ	5 U	5 U	5 U	5 U	
TOLUENE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
trans-1,3-DICHLOROPROPENE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
1,1,2-TRICHLOROETHANE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
TETRACHLOROETHYLENE(PCE)	UG/L	10 -	10 -	3 -	2 -	1 U		20 -
2-HEXANONE	UG/L	5 U	5 U	5 U	5 U	5 U	5 U	
DIBROMOCHLOROMETHANE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
CHLOROBENZENE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
ETHYLBENZENE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
XYLENES, TOTAL	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	

Analytical Data Summary
Volatile Organics in Groundwater
Zone 5 RI Supplemental Sampling 1998
Kelly AFB

	StationID	SS050MW334	SS050MW334	SS050MW335	SS050MW336	SS050MW337	SS050MW338	SS050MW338
	Alias	MW12-4	MW12-4	MW12-5	MW12-6	MW12-7	MW12-8	MW12-8
	SampleID	SIA013	SIA014FD1	SIA019	SIA022	SIA032	SIA035	SIA035LR1
	Depth	0-0	0-0	0-0	0-0	0-0	0-0	0-0
Parameter								
STYRENE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
BROMOFORM	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	
1,1,2,2-TETRACHLOROETHANE	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	

Analytical Summary
Volatile Organics in Groundwater
Zone 5 RI Supplemental Sampling 1998
Kelly AFB

	StationID	SS050MW338	SS050MW338	SS050MW339	SS050MW340	SS050MW341	SS050MW342	SS050MW343
	Alias	MW12-8	MW12-8	MW12-9	MW12-10	MW12-11	MW12-12	MW12-13
	SampleID	SIA036FD1	SIA036FD1LR1	SIA038	SIA059	SIA061	SIA028	SIA045
	Depth	0-0	0-0	0-0	0-0	0-0	0-0	0-0
Parameter								
CHLOROMETHANE	UG/L	1 U		1 U	1 U	1 U	1 U	1 U
VINYL CHLORIDE	UG/L	1 U		1 U	1 U	1 U	1 U	1 U
BROMOMETHANE	UG/L	1 UJ		1 UJ	1 U	1 U	1 U	1 U
CHLOROETHANE	UG/L	1 U		1 UJ	1 U	1 U	1 U	1 U
1,1-DICHLOROETHENE	UG/L	1 U		1 U	1 U	1 U	1 U	1 U
ACETONE	UG/L	5 U		5 U	5 U	5 UJ	16 -	5 U
CARBON DISULFIDE	UG/L	1 U		1 UJ	1 U	1 U	1 U	1 U
METHYLENE CHLORIDE	UG/L	2 U		2 UJ	2 U	2 U	2 U	2 U
1,1-DICHLOROETHANE	UG/L	1 U		1 U	1 U	1 U	1 U	1 U
VINYL ACETATE	UG/L	5 U		5 U	5 U	5 UJ	5 U	5 U
TOTAL 1,2-DICHLOROETHENE	UG/L	1 -		1 U	1 U	1 U	1 U	1 U
METHYL ETHYL KETONE (2-BUTANONE)	UG/L	5 U		5 UJ	5 U	5 UJ	8 -	5 U
CHLOROFORM	UG/L	1 U		1 U	1 U	1 U	1 U	1 U
1,1,1-TRICHLOROETHANE	UG/L	1 U		1 UJ	1 U	1 U	1 U	1 U
CARBON TETRACHLORIDE	UG/L	1 U		1 UJ	1 U	1 U	1 U	1 U
BENZENE	UG/L	1 U		1 U	1 U	1 U	1 -	1 U
1,2-DICHLOROETHANE	UG/L	1 U		1 U	1 U	1 U	1 U	1 U
TRICHLOROETHYLENE (TCE)	UG/L	4 -		4 -	2 -	3 -	1 U	1 U
1,2-DICHLOROPROPANE	UG/L	1 U		1 U	1 U	1 U	1 U	1 U
BROMODICHLOROMETHANE	UG/L	1 U		1 U	1 U	1 U	1 U	1 U
cis-1,3-DICHLOROPROPENE	UG/L	1 U		1 U	1 U	1 U	1 U	1 U
METHYL ISOBUTYL KETONE (4-METHYL-2-PENTANONE)	UG/L	5 U		5 U	5 U	5 UJ	5 U	5 U
TOLUENE	UG/L	1 U		1 U	1 U	1 U	1 U	1 U
trans-1,3-DICHLOROPROPENE	UG/L	1 U		1 U	1 U	1 U	1 U	1 U
1,1,2-TRICHLOROETHANE	UG/L	1 U		1 U	1 U	1 U	1 U	1 U
TETRACHLOROETHYLENE(PCE)	UG/L		21 -	15 -	1 U	9 -	1 U	1 U
2-HEXANONE	UG/L	5 U		5 U	5 U	5 UJ	5 U	5 U
DIBROMOCHLOROMETHANE	UG/L	1 U		1 U	1 U	1 U	1 U	1 U
CHLOROBENZENE	UG/L	1 U		1 U	1 U	1 U	1 U	1 U
ETHYLBENZENE	UG/L	1 U		1 U	1 U	1 U	1 U	1 U
XYLENES, TOTAL	UG/L	1 U		1 U	1 U	1 U	1 U	1 U

Analytical Data Summary
Volatile Organics in Groundwater
Zone 5 RI Supplemental Sampling 1998
Kelly AFB

	StationID	SS050MW338	SS050MW338	SS050MW339	SS050MW340	SS050MW341	SS050MW342	SS050MW343
	Alias	MW12-8	MW12-8	MW12-9	MW12-10	MW12-11	MW12-12	MW12-13
	SampleID	SIA036FD1	SIA036FD1LR1	SIA038	SIA059	SIA061	SIA028	SIA045
	Depth	0-0	0-0	0-0	0-0	0-0	0-0	0-0
Parameter								
STYRENE	UG/L	1 U		1 U	1 U	1 U	1 U	1 U
BROMOFORM	UG/L	1 U		1 U	1 U	1 U	1 U	1 U
1,1,2,2-TETRACHLOROETHANE	UG/L	1 U		1 U	1 U	1 U	1 U	1 U

Analytical L .. Summary
Volatile Organics In Groundwater
Zone 5 RI Supplemental Sampling 1998
Kelly AFB

Parameter		StationID	SS050MW345	SS050MW468	SS050MW468	SS050MW468	SS050MW468	SS050MW469	SS050MW469
		Alias	MW12-15	MW12-1	MW12-1	MW12-1	MW12-1	MW12-2	MW12-2
		SampleID	SIA046	SIA049	SIA049LR1	SIA050FD1	SIA050FD1LR1	SIA051	SIA051LR1
		Depth	0-0	0-0	0-0	0-0	0 0	0-0	0 0
CHLOROMETHANE	UG/L		1 U	1 U		1 U		1 U	
VINYL CHLORIDE	UG/L		1 U	12 -		12 -		1 U	
BROMOMETHANE	UG/L		1 U	1 U		1 U		1 U	
CHLOROETHANE	UG/L		1 U	1 U		1 U		1 U	
1,1-DICHLOROETHENE	UG/L		1 U	1 U		1 U		1 U	
ACETONE	UG/L		38 U	5 U		5 U		5 U	
CARBON DISULFIDE	UG/L		1 U	1 U		1 U		1 U	
METHYLENE CHLORIDE	UG/L		2 U	2 U		2 U		2 U	
1,1-DICHLOROETHANE	UG/L		1 U	2 -		3 -		1 U	
VINYL ACETATE	UG/L		5 U	5 U		5 U		5 U	
TOTAL 1,2-DICHLOROETHENE	UG/L		1 U		84 -		87 -	17 -	
METHYL ETHYL KETONE (2-BUTANONE)	UG/L		10 -	5 U		5 U		5 U	
CHLOROFORM	UG/L		1 U	1 U		1 U		1 U	
1,1,1-TRICHLOROETHANE	UG/L		1 U	1 U		1 U		1 U	
CARBON TETRACHLORIDE	UG/L		1 U	1 U		1 U		1 U	
BENZENE	UG/L		1 -	1 U		1 U		1 U	
1,2-DICHLOROETHANE	UG/L		1 U	1 U		1 U		1 U	
TRICHLOROETHYLENE (TCE)	UG/L		1 U		49 -		46 -		31 -
1,2-DICHLOROPROPANE	UG/L		1 U	1 U		1 U		1 U	
BROMODICHLOROMETHANE	UG/L		1 U	1 U		1 U		1 U	
cis-1,3-DICHLOROPROPENE	UG/L		1 U	1 U		1 U		1 U	
METHYL ISOBUTYL KETONE (4-METHYL-2-PENTANONE)	UG/L		5 U	5 U		5 U		5 U	
TOLUENE	UG/L		2 -	1 U		1 U		1 U	
trans-1,3-DICHLOROPROPENE	UG/L		1 U	1 U		1 U		1 U	
1,1,2-TRICHLOROETHANE	UG/L		1 U	1 U		1 U		1 U	
TETRACHLOROETHYLENE(PCE)	UG/L		1 U	4 -		4 -		1 U	
2-HEXANONE	UG/L		5 U	5 U		5 U		5 U	
DIBROMOCHLOROMETHANE	UG/L		1 U	1 U		1 U		1 U	
CHLOROBENZENE	UG/L		1 U	1 -		1 -		1 U	
ETHYLBENZENE	UG/L		1 U	1 U		1 U		1 U	
XYLENES, TOTAL	UG/L		1 U	1 U		1 U		1 U	

Analytical Data Summary
Volatile Organics in Groundwater
Zone 5 RI Supplemental Sampling 1998
Kelly AFB

Parameter		StationID	SS050MW345	SS050MW468	SS050MW468	SS050MW468	SS050MW469	SS050MW469	SS050MW469
		Alias	MW12-15	MW12-1	MW12-1	MW12-1	MW12-1	MW12-2	MW12-2
		SampleID	SIA046	SIA049	SIA049LR1	SIA050FD1	SIA050FD1LR1	SIA051	SIA051LR1
		Depth	0-0	0-0	0-0	0-0	0-0	0-0	0-0
STYRENE	UG/L		1 U	1 U		1 U		1 U	
BROMOFORM	UG/L		1 U	1 U		1 U		1 U	
1,1,2,2-TETRACHLOROETHANE	UG/L		1 U	1 U		1 U		1 U	

Analytical L Summary
Volatile Organics in Groundwater
Zone 5 RI Supplemental Sampling 1998
Kelly AFB

Parameter		StationID	SS050MW470	SS050MW470	SS050MW471	SS050MW471	SS050MW472	SS050MW473
		Alias	MW12-3	MW12-3	MW12-18	MW12-18	MW12-16	MW12-17
		SampleID	SIA052	SIA052LR1	SIA053	SIA053LR1	SIA057	SIA058
		Depth	0-0	0-0	0 0	0 0	0-0	0 0
CHLOROMETHANE	UG/L		1 U		1 U		1 U	1 U
VINYL CHLORIDE	UG/L		1 U		1 U		1 U	1 U
BROMOMETHANE	UG/L		1 U		1 U		1 U	1 U
CHLOROETHANE	UG/L		1 U		1 U		1 U	1 U
1,1-DICHLOROETHENE	UG/L		1 -		1 U		1 U	1 U
ACETONE	UG/L		5 U		5 U		5 U	5 U
CARBON DISULFIDE	UG/L		1 U		1 U		1 U	1 U
METHYLENE CHLORIDE	UG/L		2 U		2 U		2 U	2 U
1,1-DICHLOROETHANE	UG/L		2 -		2 -		1 U	1 U
VINYL ACETATE	UG/L		5 U		5 U		5 U	5 U
TOTAL 1,2-DICHLOROETHENE	UG/L			340 -		260 -	1 U	1 U
METHYL ETHYL KETONE (2-BUTANONE)	UG/L		5 U		5 U		5 U	5 U
CHLOROFORM	UG/L		1 U		1 U		1 U	1 U
1,1,1-TRICHLOROETHANE	UG/L		1 U		1 U		1 U	1 U
CARBON TETRACHLORIDE	UG/L		1 U		1 U		1 U	1 U
BENZENE	UG/L		1 U		1 U		4 -	1 U
1,2-DICHLOROETHANE	UG/L		1 U		1 U		1 U	1 U
TRICHLOROETHYLENE (TCE)	UG/L			640 -		400 -	1 U	1 U
1,2-DICHLOROPROPANE	UG/L		1 U		1 U		1 U	1 U
BROMODICHLOROMETHANE	UG/L		1 U		1 U		1 U	1 U
cis-1,3-DICHLOROPROPENE	UG/L		1 U		1 U		1 U	1 U
METHYL ISOBUTYL KETONE (4-METHYL-2-PENTANONE)	UG/L		5 U		5 U		5 U	5 U
TOLUENE	UG/L		1 U		1 U		1 U	1 U
trans-1,3-DICHLOROPROPENE	UG/L		1 U		1 U		1 U	1 U
1,1,2-TRICHLOROETHANE	UG/L		1 U		1 U		1 U	1 U
TETRACHLOROETHYLENE(PCE)	UG/L		2 -		1 -		1 U	1 U
2-HEXANONE	UG/L		5 U		5 U		5 U	5 U
DIBROMOCHLOROMETHANE	UG/L		1 U		1 U		1 U	1 U
CHLOROBENZENE	UG/L		1 U		1 U		1 U	1 U
ETHYLBENZENE	UG/L		1 U		1 U		1 U	1 U
XYLENES, TOTAL	UG/L		1 U		1 U		1 U	1 U

Analytical Data Summary
Volatile Organics in Groundwater
Zone 5 RI Supplemental Sampling 1998
Kelly AFB

	StationID	SS050MW470	SS050MW470	SS050MW471	SS050MW471	SS050MW472	SS050MW473
	Alias	MW12-3	MW12-3	MW12-18	MW12-18	MW12-16	MW12-17
	SampleID	SIA052	SIA052LR1	SIA053	SIA053LR1	SIA057	SIA058
	Depth	0-0	0-0	0-0	0-0	0-0	0-0
Parameter							
STYRENE	UG/L	1 U		1 U		1 U	1 U
BROMOFORM	UG/L	1 U		1 U		1 U	1 U
1,1,2,2-TETRACHLOROETHANE	UG/L	1 U		1 U		1 U	1 U

Analytical Summary
Semivolatile Organics in Groundwater
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS050MW334	SS050MW334	SS050MW335	SS050MW336	SS050MW337	SS050MW338	SS050MW338
	Alias	MW12-4	MW12-4	MW12-5	MW12-6	MW12-7	MW12-8	MW12-8
	SampleID	SIA013	SIA014FD1	SIA019	SIA022	SIA032	SIA035	SIA036FD1
	Depth	0-0	0-0	0-0	0-0	0-0	0-0	0-0
Parameter								
PHENOL	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
bis(2-CHLOROETHYL) ETHER (2-CHLOROETHYL ETHER)	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
2-CHLOROPHENOL	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
1,3-DICHLOROBENZENE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
1,4-DICHLOROBENZENE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-DICHLOROBENZENE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
2-METHYLPHENOL (o-CRESOL)	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
2,2'-OXYBIS(1-CHLORO)PROPANE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
4-METHYLPHENOL (p-CRESOL)	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
N-NITROSODI-n-PROPYLAMINE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
HEXACHLOROETHANE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
NITROBENZENE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
ISOPHORONE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
2-NITROPHENOL	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
2,4-DIMETHYLPHENOL	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
bis(2-CHLOROETHOXY) METHANE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
2,4-DICHLOROPHENOL	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2,4-TRICHLOROBENZENE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
NAPHTHALENE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
4-CHLOROANILINE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
HEXACHLOROBUTADIENE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
4-CHLORO-3-METHYLPHENOL	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
2-METHYLNAPHTHALENE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
HEXACHLOROCYCLOPENTADIENE	UG/L	11 UJ	10 UJ	10 UJ	10 UJ	10 U	10 UJ	10 UJ
2,4,6-TRICHLOROPHENOL	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
2,4,5-TRICHLOROPHENOL	UG/L	26 U	25 U	24 U	26 U	24 U	25 U	25 U
2-CHLORONAPHTHALENE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
2-NITROANILINE	UG/L	26 U	25 U	24 U	26 U	24 U	25 U	25 U
DIMETHYL PHTHALATE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
2,6-DINITROTOLUENE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
ACENAPHTHYLENE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U

Analytical Data Summary
Semivolatile Organics in Groundwater
Zone 5 RI Supplemental Sampling
Kelly AFB

Parameter		StationID	SS050MW334	SS050MW334	SS050MW335	SS050MW336	SS050MW337	SS050MW338	SS050MW338
		Alias	MW12-4	MW12-4	MW12-5	MW12-6	MW12-7	MW12-8	MW12-8
		SampleID	SIA013	SIA014FD1	SIA019	SIA022	SIA032	SIA035	SIA036FD1
		Depth	0-0	0-0	0-0	0-0	0-0	0-0	0-0
3-NITROANILINE	UG/L		26 U	25 U	24 U	26 U	24 U	25 U	25 U
ACENAPHTHENE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
2,4-DINITROPHENOL	UG/L		26 U	25 U	24 U	26 U	24 U	25 UJ	25 UJ
4-NITROPHENOL	UG/L		26 U	25 U	24 U	26 U	24 U	25 U	25 U
DIBENZOFURAN	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
2,4-DINITROTOLUENE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
DIETHYL PHTHALATE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
FLUORENE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
4-CHLOROPHENYL PHENYL ETHER	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
4-NITROANILINE	UG/L		26 UJ	25 UJ	24 UJ	26 UJ	24 U	25 U	25 U
4,6-DINITRO-2-METHYLPHENOL	UG/L		26 U	25 U	24 U	26 U	24 U	25 U	25 U
N-NITROSODIPHENYLAMINE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
4-BROMOPHENYL PHENYL ETHER	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
HEXACHLOROBENZENE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
PENTACHLOROPHENOL	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
PHENANTHRENE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
ANTHRACENE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
CARBAZOLE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
DI-n-BUTYL PHTHALATE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
FLUORANTHENE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
PYRENE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
BENZYL BUTYL PHTHALATE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
BENZO(a)ANTHRACENE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
3,3'-DICHLOROBENZIDINE	UG/L		11 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 U	10 U
CHRYSENE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
bis(2-ETHYLHEXYL) PHTHALATE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
DI-n-OCTYLPHTHALATE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
BENZO(b)FLUORANTHENE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
BENZO(k)FLUORANTHENE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
BENZO(a)PYRENE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U
INDENO(1,2,3-c,d)PYRENE	UG/L		11 U	10 U	10 U	10 U	10 U	10 U	10 U

Analytical L... Summary
Semivolatile Organics in Groundwater
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS050MW334	SS050MW334	SS050MW335	SS050MW336	SS050MW337	SS050MW338	SS050MW338
	Alias	MW12-4	MW12-4	MW12-5	MW12-6	MW12-7	MW12-8	MW12-8
	SampleID	SIA013	SIA014FD1	SIA019	SIA022	SIA032	SIA035	SIA036FD1
	Depth	0-0	0-0	0-0	0-0	0-0	0-0	0-0
Parameter								
DIBENZ(a,h)ANTHRACENE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U
BENZO(g,h,i)PERYLENE	UG/L	11 U	10 U	10 U	10 U	10 U	10 U	10 U

Analytical Data Summary
Semivolatile Organics In Groundwater
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS050MW339	SS050MW340	SS050MW341	SS050MW343	SS050MW472	SS050MW473
	Alias	MW12-9	MW12-10	MW12-11	MW12-13	MW12-16	MW12-17
	SampleID	SIA038	SIA059	SIA061	SIA045	SIA057	SIA058
	Depth	0-0	0-0	0-0	0-0	0-0	0-0
Parameter							
PHENOL	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
bis(2-CHLOROETHYL) ETHER (2-CHLOROETHYL ETHER)	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
2-CHLOROPHENOL	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
1,3-DICHLOROBENZENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
1,4-DICHLOROBENZENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
1,2-DICHLOROBENZENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
2-METHYLPHENOL (o-CRESOL)	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
2,2'-OXYBIS(1-CHLORO)PROPANE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
4-METHYLPHENOL (p-CRESOL)	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
N-NITROSODI-n-PROPYLAMINE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
HEXACHLOROETHANE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
NITROBENZENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
ISOPHORONE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
2-NITROPHENOL	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
2,4-DIMETHYLPHENOL	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
bis(2-CHLOROETHOXY) METHANE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
2,4-DICHLOROPHENOL	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
1,2,4-TRICHLOROBENZENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
NAPHTHALENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
4-CHLOROANILINE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
HEXACHLOROBUTADIENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
4-CHLORO-3-METHYLPHENOL	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
2-METHYLNAPHTHALENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
HEXACHLOROCYCLOPENTADIENE	UG/L	10 UJ	10 U	10 U	10 U	10 U	10 U
2,4,6-TRICHLOROPHENOL	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
2,4,5-TRICHLOROPHENOL	UG/L	25 U	25 U	26 U	24 U	25 U	25 U
2-CHLORONAPHTHALENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
2-NITROANILINE	UG/L	25 U	25 U	26 U	24 U	25 U	25 U
DIMETHYL PHTHALATE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
2,6-DINITROTOLUENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
ACENAPHTHYLENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U

Analytical L ummary
Semivolatile Organics in Groundwater
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS050MW339	SS050MW340	SS050MW341	SS050MW343	SS050MW472	SS050MW473
	Alias	MW12-9	MW12-10	MW12-11	MW12-13	MW12-16	MW12-17
	SampleID	SIA038	SIA059	SIA061	SIA045	SIA057	SIA058
	Depth	0-0	0-0	0-0	0-0	0-0	0-0
Parameter							
3-NITROANILINE	UG/L	25 U	25 U	26 U	24 U	25 U	25 U
ACENAPHTHENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
2,4-DINITROPHENOL	UG/L	25 UJ	25 U	26 U	24 U	25 U	25 U
4-NITROPHENOL	UG/L	25 U	25 U	26 U	24 U	25 U	25 U
DIBENZOFURAN	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
2,4-DINITROTOLUENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
DIETHYL PHTHALATE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
FLUORENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
4-CHLOROPHENYL PHENYL ETHER	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
4-NITROANILINE	UG/L	25 U	25 U	26 U	24 U	25 U	25 U
4,6-DINITRO-2-METHYLPHENOL	UG/L	25 U	25 U	26 U	24 U	25 U	25 U
N-NITROSODIPHENYLAMINE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
4-BROMOPHENYL PHENYL ETHER	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
HEXACHLOROBENZENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
PENTACHLOROPHENOL	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
PHENANTHRENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
ANTHRACENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
CARBAZOLE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
DI-n-BUTYL PHTHALATE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
FLUORANTHENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
PYRENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
BENZYL BUTYL PHTHALATE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
BENZO(a)ANTHRACENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
3,3'-DICHLOROBENZIDINE	UG/L	10 U	10 UJ	10 UJ	10 U	10 UJ	10 UJ
CHRYSENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
bis(2-ETHYLHEXYL) PHTHALATE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
DI-n-OCTYLPHTHALATE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
BENZO(b)FLUORANTHENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
BENZO(k)FLUORANTHENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
BENZO(a)PYRENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
INDENO(1,2,3-c,d)PYRENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U

Analytical Data Summary
Semivolatile Organics in Groundwater
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS050MW339	SS050MW340	SS050MW341	SS050MW343	SS050MW472	SS050MW473
	Alias	MW12-9	MW12-10	MW12-11	MW12-13	MW12-16	MW12-17
	SampleID	SIA038	SIA059	SIA061	SIA045	SIA057	SIA058
	Depth	0-0	0-0	0-0	0-0	0-0	0-0
Parameter							
DIBENZ(a,h)ANTHRACENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U
BENZO(g,h,i)PERYLENE	UG/L	10 U	10 U	10 U	10 U	10 U	10 U

Analytical Summary
Total Metals in Groundwater
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS050MW334	SS050MW334	SS050MW335	SS050MW336	SS050MW337	SS050MW338	SS050MW338	SS050MW339	SS050MW340
	Alias	MW12-4	MW12-4	MW12-5	MW12-6	MW12-7	MW12-8	MW12-8	MW12-9	MW12-10
	SampleID	SIA013	SIA014FD1	SIA019	SIA022	SIA032	SIA035	SIA036FD1	SIA038	SIA059
	Depth	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0
Parameter										
ANTIMONY	UG/L	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
ARSENIC	UG/L	1.7 U	1.7 U	2 J	2.8 J	1.8 J	1.7 U	1.7 U	1.7 U	1.8 J
BARIUM	UG/L	130 -	129 -	123 -	128 -	118 -	113 -	113 -	138 -	46.5 -
BERYLLIUM	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
CADMIUM	UG/L	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
CHROMIUM, TOTAL	UG/L	4 U	4 U	14.7 -	6.9 J	8.7 J	4 U	4 U	4 U	4 U
COBALT	UG/L	4 U	4 U	4.5 J	4 J	4 U	4 U	4 U	4 U	4 U
COPPER	UG/L	2 U	2 U	3.4 J	4.1 J	10.8 -	2 U	2 U	2 U	2 U
IRON	UG/L	442 -	413 -	4550 -	4150 -	348 -	308 -	252 -	511 -	411 -
LEAD	UG/L	2 U	2 U	2 U	3 U	2 U	2 U	2 U	2 U	2 U
MANGANESE	UG/L	58.1 -	56.8 -	123 -	188 -	46.3 -	105 -	108 -	83.9 -	71.4 -
MERCURY	UG/L	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
NICKEL	UG/L	8 U	8 U	23.9 -	37.5 -	14.4 J	8 U	8 U	11 J	8 U
SELENIUM	UG/L	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	1.5 UJ
SILVER	UG/L	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
THALLIUM	UG/L	5 U	5 U	5 U	5 U	1 U	1 U	1 U	1 U	1 UJ
VANADIUM	UG/L	11.2 -	11.1 -	17 -	20.6 -	5.9 J	5 J	5.8 J	8 J	16.4 -
ZINC	UG/L	5 U	5 U	6.5 J	13.3 U	5 U	5 U	5 U	5 U	5 U

Analytical Data Summary
Total Metals in Groundwater
Zone 5 RI Supplemental Sampling
Kelly AFB

	StationID	SS050MW341	SS050MW343	SS050MW468	SS050MW468	SS050MW469	SS050MW470	SS050MW471	SS050MW472	SS050MW473
	Alias	MW12-11	MW12-13	MW12-1	MW12-1	MW12-2	MW12-3	MW12-18	MW12-16	MW12-17
	SampleID	SIA061	SIA045	SIA049	SIA050FD1	SIA051	SIA052	SIA053	SIA057	SIA058
	Depth	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0
Parameter										
ANTIMONY	UG/L	2 U	2 UJ	2 U	2 U	2 U	2 U	2 U	2 U	2 U
ARSENIC	UG/L	1.9 J	1.7 U	1.9 J	1.7 U	1.7 U	2.2 J	1.7 U	3.7 J	18.4 -
BARIUM	UG/L	126 -	54.4 -	54.2 -	53 -	32.5 -	74.9 -	74.4 -	161 -	254 -
BERYLLIUM	UG/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
CADMIUM	UG/L	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
CHROMIUM, TOTAL	UG/L	4 U	4 U	4 U	4 U	4 U	4 U	6.8 J	4 U	4 U
COBALT	UG/L	4 U	4 U	4.7 J	4 U	4 U	4 U	4 U	4 U	4 U
COPPER	UG/L	2 U	3.7 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
IRON	UG/L	801 -	117 -	395 -	401 -	346 -	932 -	228 -	523 -	1180 -
LEAD	UG/L	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
MANGANESE	UG/L	126 -	21.3 -	384 -	378 -	23.6 -	107 -	36.5 -	390 -	931 -
MERCURY	UG/L	0.1 U	0.1 U	0.1 R	0.1 R	0.1 R	0.1 R	0.1 R	0.1 U	0.1 U
NICKEL	UG/L	8 U	8 U	8 U	8 U	8 U	8 U	8 U	8 U	8.1 J
SELENIUM	UG/L	1.5 UJ	1.5 U	1.5 U	1.5 U	1.5 U	1.5 U	2.6 J	1.5 UJ	1.5 UJ
SILVER	UG/L	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
THALLIUM	UG/L	1 UJ	1 UJ	1 U	1 U	1 U	1 U	1 U	1.1 J	1 UJ
VANADIUM	UG/L	9.3 J	9.7 J	10.9 -	10.4 -	9.6 J	11.7 -	7.6 J	4.8 J	3.2 J
ZINC	UG/L	5 U	5 U	5.1 U	5 U	5 U	6.3 U	5 U	5 U	5 U

Appendix F

Summary of Groundwater Data

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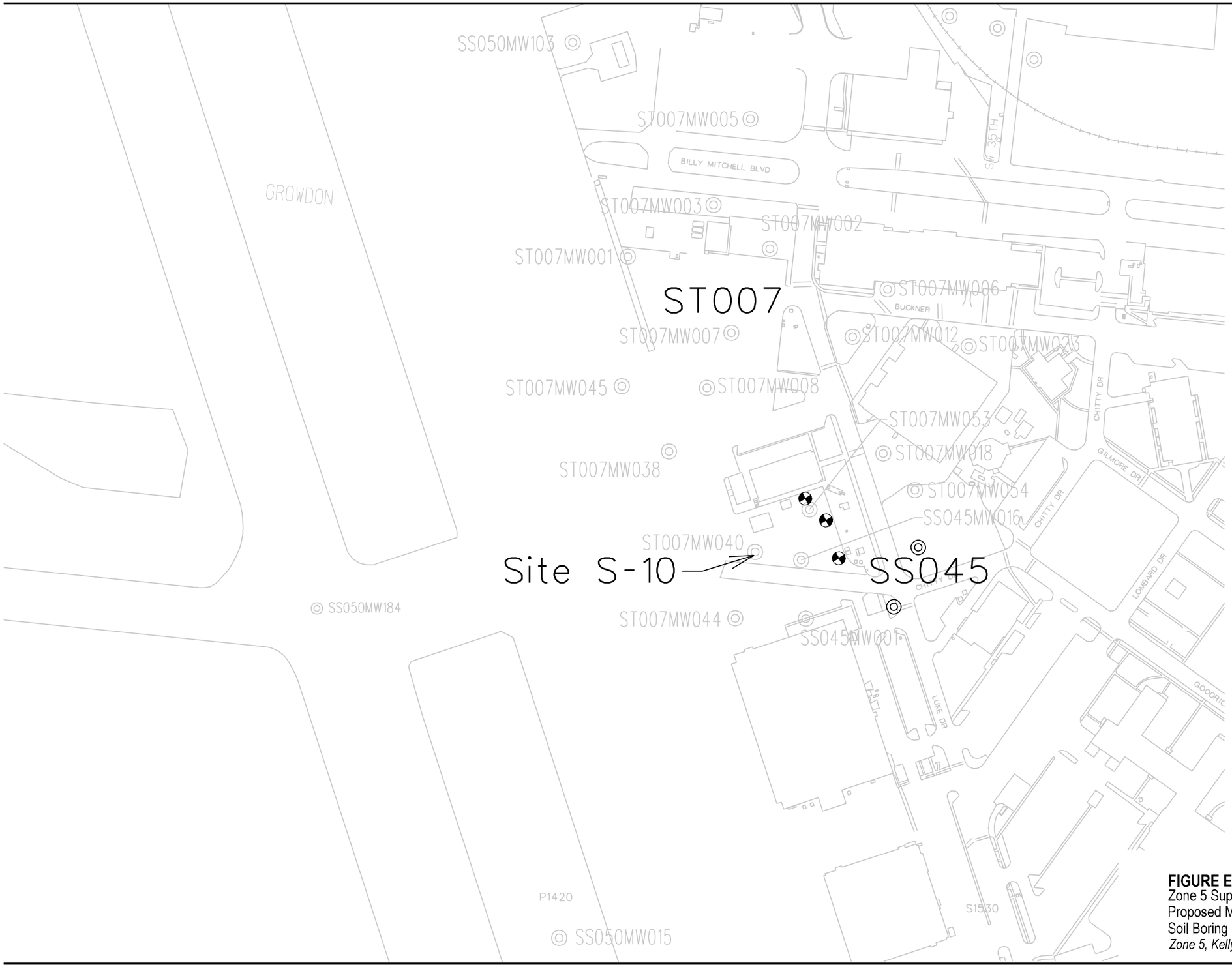
TABLE F.1
Summary of Groundwater Data
Kelly AFB, San Antonio, Texas

Constituent Name (units)	Number of Samples	Number of Wells	Detects	Number of Wells with Detects	Minimum	Maximum	Average
1,1,1,2-TETRACHLOROETHANE (µg/L)	393	91	0	0	-	-	-
1,1,1-TRICHLOROETHANE (µg/L)	853	205	4	2	2	230	123.00
1,1,2,2-TETRACHLOROETHANE (µg/L)	841	201	0	0	-	-	-
1,1,2-TRICHLOROETHANE (µg/L)	853	205	3	2	1.55	8	3.70
1,1-DICHLOROETHANE (µg/L)	854	205	8	3	2	210	103.88
1,1-DICHLOROETHENE (µg/L)	853	205	22	12	1	81	12.43
1,1-DICHLOROPROPENE (µg/L)	381	87	3	2	5.4	6.57	6.18
1,2,3-TRICHLOROBENZENE (µg/L)	381	87	4	3	0.45	15.5	6.98
1,2,3-TRICHLOROPROPANE (µg/L)	381	87	2	1	13.7	13.7	13.70
1,2,4-TRICHLOROBENZENE (µg/L)	969	200	4	1	11.1	217	69.65
1,2,4-TRIMETHYLBENZENE (µg/L)	381	87	12	6	1.7	114	22.23
1,2-DIBROMO-3-CHLOROPROPANE (µg/L)	415	116	0	0	-	-	-
1,2-DIBROMOETHANE (ETHYLENE DIBROMIDE) (µg/L)	415	116	0	0	-	-	-
1,2-DICHLOROBENZENE (µg/L)	1020	199	58	17	0.3	24300	754.05
1,2-DICHLOROETHANE (µg/L)	853	205	2	2	8	10	9.00
1,2-DICHLOROETHANE-D4 (µg/L)	18	15	18	15	44.5	280	70.36
1,2-DICHLOROPROPANE (µg/L)	853	205	0	0	-	-	-
1,3,5-TRIMETHYLBENZENE (MESITYLENE) (µg/L)	382	87	13	6	0.67	50	8.50
1,3-DICHLOROBENZENE (µg/L)	1018	199	43	14	1	844	78.70
1,3-DICHLOROPROPANE (µg/L)	381	87	1	1	1.1	1.1	1.10
1,4-DICHLOROBENZENE (µg/L)	1024	199	75	21	0.43	2410	147.45
1-BROMO-4-FLUOROBENZENE (4-BROMOFLUOROBENZENE) (µg/L)	182	135	182	135	48	280	95.26
1-CHLORONAPHTHALENE (µg/L)	282	82	0	0	-	-	-
1-METHYLNAPHTHALENE (µg/L)	284	82	15	5	5.96	90.9	29.43
2,2'-OXYBIS(1-CHLORO)PROPANE (µg/L)	296	172	0	0	-	-	-
2,2-DICHLOROPROPANE (µg/L)	381	87	0	0	-	-	-
2,4,5-TRICHLOROPHENOL (µg/L)	588	195	0	0	-	-	-
2,4,6-TRIBROMOPHENOL (µg/L)	27	24	27	24	1.5	105	65.69
2,4,6-TRICHLOROPHENOL (µg/L)	557	189	0	0	-	-	-
2,4-DICHLOROPHENOL (µg/L)	588	195	2	1	1.17	1.61	1.39
2,4-DIMETHYLPHENOL (µg/L)	589	195	9	4	2.18	150	33.72
2,4-DINITROPHENOL (µg/L)	588	195	0	0	-	-	-
2,4-DINITROTOLUENE (µg/L)	548	186	0	0	-	-	-
2,6-DINITROTOLUENE (µg/L)	588	195	0	0	-	-	-
2-CHLORONAPHTHALENE (µg/L)	588	195	0	0	-	-	-
2-CHLOROPHENOL (µg/L)	591	195	22	7	2.92	108	28.01
2-CHLOROTOLUENE (µg/L)	382	87	18	7	0.54	9.2	4.20
2-FLUOROBIPHENYL (µg/L)	27	24	27	24	0	81	57.96
2-FLUOROPHENOL (µg/L)	27	24	27	24	0	87	51.32
2-HEXANONE (µg/L)	472	186	0	0	-	-	-
2-METHYLNAPHTHALENE (µg/L)	591	195	21	11	2.78	430	70.28
2-METHYLPHENOL (o-CRESOL) (µg/L)	588	195	3	2	2.21	5.73	4.25
2-NITROANILINE (µg/L)	588	195	0	0	-	-	-
2-NITROPHENOL (µg/L)	588	195	1	1	19.6	19.6	19.60
3,3'-DICHLOROBENZIDINE (µg/L)	578	193	0	0	-	-	-
3,3'-DIMETHYLBENZIDINE (µg/L)	10	10	0	0	-	-	-
3-METHYLPHENOL (µg/L)	10	10	0	0	-	-	-
3-NITROANILINE (µg/L)	588	195	0	0	-	-	-
4,6-DINITRO-2-METHYLPHENOL (µg/L)	588	195	0	0	-	-	-
4-BROMOPHENYL PHENYL ETHER (µg/L)	588	195	0	0	-	-	-
4-CHLORO-3-METHYLPHENOL (µg/L)	589	195	1	1	15	15	15.00
4-CHLOROANILINE (µg/L)	588	195	1	1	22.3	22.3	22.30
4-CHLOROPHENYL PHENYL ETHER (µg/L)	588	195	0	0	-	-	-
4-CHLOROTOLUENE (µg/L)	381	87	7	6	1.04	9.36	4.51
4-METHYLPHENOL (p-CRESOL) (µg/L)	588	195	0	0	-	-	-
4-NITROANILINE (µg/L)	588	195	0	0	-	-	-
4-NITROPHENOL (µg/L)	588	195	0	0	-	-	-
ACENAPHTHENE (µg/L)	595	201	1	1	60	60	60.00
ACENAPHTHYLENE (µg/L)	595	201	1	1	179	179	179.00
ACETONE (µg/L)	472	186	4	4	8	350	115.75

Constituent Name (units)	Number of Samples	Number of Wells	Detects	Number of Wells with Detects	Minimum	Maximum	Average
ALDRIN (µg/L)	345	157	0	0	-	-	-
ALKALINITY, TOTAL (AS CaCO3) ()			0	0	-	-	-
ALPHA BHC (ALPHA HEXACHLOROCYCLOHEXANE) (µg/L)	345	157	0	0	-	-	-
ALPHA ENDOSULFAN (µg/L)	345	157	0	0	-	-	-
ALPHA-CHLORDANE (µg/L)	121	115	0	0	-	-	-
ANILINE (PHENYLAMINE, AMINOBENZENE) (µg/L)	282	82	0	0	-	-	-
ANTHRACENE (µg/L)	595	201	0	0	-	-	-
ANTIMONY (µg/L)	777	197	6	5	2	127	44.23
ARSENIC (µg/L)	777	197	86	54	1.7	307	31.80
AZOBENZENE (µg/L)	282	82	0	0	-	-	-
BARIUM (µg/L)	775	178	522	174	19.1	2640	187.75
BENZENE (µg/L)	912	205	100	37	0.42	2020	372.66
BENZIDINE (µg/L)	282	82	0	0	-	-	-
BENZO(a)ANTHRACENE (µg/L)	595	201	0	0	-	-	-
BENZO(a)PYRENE (µg/L)	595	201	0	0	-	-	-
BENZO(b)FLUORANTHENE (µg/L)	595	201	0	0	-	-	-
BENZO(g,h,i)PERYLENE (µg/L)	595	201	0	0	-	-	-
BENZO(k)FLUORANTHENE (µg/L)	595	201	0	0	-	-	-
BENZO[E]PYRENE (µg/L)	282	82	0	0	-	-	-
BENZOIC ACID (µg/L)	292	84	0	0	-	-	-
BENZYL ALCOHOL (µg/L)	292	84	0	0	-	-	-
BENZYL BUTYL PHTHALATE (µg/L)	588	195	8	6	2.03	14.9	10.27
BERYLLIUM (µg/L)	775	178	5	5	0.5	113	23.00
BETA BHC (BETA HEXACHLOROCYCLOHEXANE) (µg/L)	345	157	0	0	-	-	-
BETA ENDOSULFAN (µg/L)	345	157	0	0	-	-	-
BIPHENYL (DIPHENYL) (µg/L)	282	82	1	1	3.42	3.42	3.42
bis(2-CHLOROETHOXY) METHANE (µg/L)	588	195	1	1	3.33	3.33	3.33
bis(2-CHLOROETHYL) ETHER (2-CHLOROETHYL ETHER) (µg/L)	588	195	0	0	-	-	-
bis(2-CHLOROISOPROPYL) ETHER (µg/L)	292	84	0	0	-	-	-
bis(2-ETHYLHEXYL) PHTHALATE (µg/L)	590	195	105	54	1.47	224	13.62
BROMACIL (µg/L)	260	79	60	22	1.03	153	23.47
BROMOBENZENE (µg/L)	381	87	1	1	0.67	0.67	0.67
BROMOCHLOROMETHANE (µg/L)	415	116	0	0	-	-	-
BROMODICHLOROMETHANE (µg/L)	853	205	0	0	-	-	-
BROMOFORM (µg/L)	853	205	0	0	-	-	-
BROMOMETHANE (µg/L)	853	205	3	2	1.19	4.61	2.33
CADMIUM (µg/L)	775	178	6	5	1.2	10	4.13
CALCIUM (µg/L)	136	126	130	122	40300	167000	113209.00
CARBAZOLE (µg/L)	538	184	0	0	-	-	-
CARBON DISULFIDE (µg/L)	471	186	1	1	6	6	6.00
CARBON TETRACHLORIDE (µg/L)	853	205	0	0	-	-	-
CHLORDANE (µg/L)	224	74	0	0	-	-	-
CHLOROBENZENE (µg/L)	920	205	112	34	0.61	21000	2089.35
CHLOROETHANE (µg/L)	853	205	2	1	1.61	1.61	1.61
CHLOROFORM (µg/L)	854	205	27	15	0.3	11	1.16
CHLOROMETHANE (µg/L)	853	205	3	3	0.64	4.83	3.01
CHROMIUM, TOTAL (µg/L)	775	178	159	74	2	6990	191.63
CHRYSENE (µg/L)	595	201	1	1	2.1	2.1	2.10
cis-1,2-DICHLOROETHYLENE (µg/L)	431	116	167	46	1	220	11.19
cis-1,3-DICHLOROPROPENE (µg/L)	853	205	0	0	-	-	-
COBALT (µg/L)	775	178	25	16	2.5	87.7	20.81
COD - CHEMICAL OXYGEN DEMAND ()			0	0	-	-	-
COPPER (µg/L)	775	178	45	36	1.5	370	60.97
CYANIDE (µg/L)	515	178	5	5	10	23	12.82
DDD (1,1-bis(CHLOROPHENYL)-2,2-DICHLOROETHANE) (µg/L)	143	137	0	0	-	-	-
DDE (1,1-bis(CHLOROPHENYL)-2,2-DICHLOROETHENE) (µg/L)	143	137	0	0	-	-	-
DDT (1,1-bis(CHLOROPHENYL)-2,2,2-TRICHLOROETHANE) (µg/L)	143	137	1	1	0.12	0.12	0.12
DELTA BHC (DELTA HEXACHLOROCYCLOHEXANE) (µg/L)	345	157	0	0	-	-	-
DI-n-BUTYL PHTHALATE (µg/L)	588	195	64	36	1.56	38.9	11.89
DI-n-OCTYLPHTHALATE (µg/L)	588	195	1	1	3.91	3.91	3.91
DIBENZ(a,h)ANTHRACENE (µg/L)	595	201	0	0	-	-	-
DIBENZOFURAN (µg/L)	588	195	2	2	1.12	3.1	2.11

Constituent Name (units)	Number of Samples	Number of Wells	Detects	Number of Wells with Detects	Minimum	Maximum	Average
DIBROMOCHLOROMETHANE (µg/L)	853	205	0	0	-	-	-
DIBROMOFLUOROMETHANE (µg/L)	164	134	164	134	87	114	98.50
DIBROMOMETHANE (µg/L)	381	87	0	0	-	-	-
DICHLORODIFLUOROMETHANE (µg/L)	382	87	5	5	1.1	50.1	11.90
DIELDRIN (µg/L)	345	157	0	0	-	-	-
DIETHYL PHTHALATE (µg/L)	580	194	12	9	1	165	19.50
DIMETHYL PHTHALATE (µg/L)	588	195	4	2	1.89	147.8	40.14
DISSOLVED OXYGEN (MG/L)	7	7	7	7	1.9	7.9	4.56
ENDOSULFAN SULFATE (µg/L)	345	157	0	0	-	-	-
ENDRIN (µg/L)	345	157	0	0	-	-	-
ENDRIN ALDEHYDE (µg/L)	345	157	0	0	-	-	-
ENDRIN KETONE (µg/L)	121	115	0	0	-	-	-
ETHYLBENZENE (µg/L)	906	205	31	16	0.62	2300	128.72
FLUORANTHENE (µg/L)	596	201	5	1	2.63	19.8	10.98
FLUORENE (µg/L)	595	201	9	5	0.9	54.7	9.41
GAMMA BHC (LINDANE) (µg/L)	345	157	0	0	-	-	-
GAMMA-CHLORDANE (µg/L)	121	115	0	0	-	-	-
HARDNESS (AS CaCO3) ()			0	0	-	-	-
HEPTACHLOR (µg/L)	345	157	0	0	-	-	-
HEPTACHLOR EPOXIDE (µg/L)	345	157	6	6	0.035	2.01	0.73
HEXACHLOROBENZENE (µg/L)	588	195	1	1	1.09	1.09	1.09
HEXACHLOROBUTADIENE (µg/L)	969	200	0	0	-	-	-
HEXACHLOROCYCLOPENTADIENE (µg/L)	588	195	0	0	-	-	-
HEXACHLOROETHANE (µg/L)	588	195	0	0	-	-	-
INDENO(1,2,3-c,d)PYRENE (µg/L)	595	201	0	0	-	-	-
IRON (µg/L)	139	126	74	71	5.42	34100	2138.50
ISOPHORONE (µg/L)	588	195	0	0	-	-	-
ISOPROPYLBENZENE (CUMENE) (µg/L)	381	87	32	12	1.7	52.3	18.35
LEAD (µg/L)	776	197	30	24	2	110	13.93
M,P-XYLENE (SUM OF ISOMERS) (µg/L)	63	12	1	1	10	10	10.00
M-XYLENE (1,3-DIMETHYLBENZENE) (µg/L)	381	87	17	11	0.5	126	21.53
MAGNESIUM ()			0	0	-	-	-
MANGANESE (µg/L)	783	178	559	177	1.5	3890	434.19
MERCURY (µg/L)	777	197	47	33	0.1	2.59	0.54
METHOXYCHLOR (µg/L)	345	157	10	10	0.07	0.299	0.12
METHYL ETHYL KETONE (2-BUTANONE) (µg/L)	472	186	2	2	12	24	18.00
METHYL ISOBUTYL KETONE (4-METHYL-2-PENTANONE) (µg/L)	472	186	1	1	33	33	33.00
METHYLENE CHLORIDE (µg/L)	851	205	13	13	0.33	16	2.54
n-BUTYLBENZENE (µg/L)	381	87	21	9	1.1	16	8.80
N-NITROSODI-n-PROPYLAMINE (µg/L)	588	195	0	0	-	-	-
N-NITROSODIMETHYLAMINE (µg/L)	282	82	0	0	-	-	-
N-NITROSODIPHENYLAMINE (µg/L)	588	195	0	0	-	-	-
n-PROPYLBENZENE (µg/L)	381	87	36	13	0.54	56.5	15.94
NAPHTHALENE (µg/L)	981	206	44	21	0.47	590	95.26
NICKEL (µg/L)	775	178	164	70	8	5610	428.53
NITROBENZENE (µg/L)	588	195	0	0	-	-	-
NITROBENZENE-D5 (µg/L)	27	24	27	24	0	93	62.39
O-XYLENE (1,2-DIMETHYLBENZENE) (µg/L)	444	91	19	9	1.15	65.8	14.24
OXIDATION-REDUCTION POTENTIAL (MILLIVOLTS)	7	7	7	7	41	232	113.86
p,p'-DDD (µg/L)	202	73	0	0	-	-	-
p,p'-DDE (µg/L)	202	73	0	0	-	-	-
p,p'-DDT (µg/L)	202	73	0	0	-	-	-
P-CYMENE (p-ISOPROPYLTOLUENE) (µg/L)	381	87	9	5	1.3	14.5	4.96
P-XYLENE (1,4-DIMETHYLBENZENE) (µg/L)	381	87	14	9	0.53	64	15.43
PCB-1016 (AROCHLOR 1016) (µg/L)	345	157	0	0	-	-	-
PCB-1221 (AROCHLOR 1221) (µg/L)	345	157	0	0	-	-	-
PCB-1232 (AROCHLOR 1232) (µg/L)	345	157	0	0	-	-	-
PCB-1242 (AROCHLOR 1242) (µg/L)	345	157	0	0	-	-	-
PCB-1248 (AROCHLOR 1248) (µg/L)	345	157	0	0	-	-	-
PCB-1254 (AROCHLOR 1254) (µg/L)	345	157	0	0	-	-	-
PCB-1260 (AROCHLOR 1260) (µg/L)	345	157	0	0	-	-	-
PENTACHLOROBENZENE (µg/L)	282	82	0	0	-	-	-
PENTACHLORONITROBENZENE (µg/L)	282	82	0	0	-	-	-
PENTACHLOROPHENOL (µg/L)	588	195	0	0	-	-	-
PETROLEUM HYDROCARBONS (MG/L)	231	155	11	8	0.1	610	56.96
pH (PH UNITS)	273	167	273	167	6.35	9.91	6.96

Constituent Name (units)	Number of Samples	Number of Wells	Detects	Number of Wells with Detects	Minimum	Maximum	Average
PHENANTHRENE (µg/L)	595	201	5	2	1.15	4.73	3.35
PHENOL (µg/L)	589	195	11	5	4.3	25.4	9.84
PHENOL-D5 (µg/L)	27	24	27	24	0	87	51.33
PYRENE (µg/L)	595	201	9	6	1.6	71.6	41.27
SEC-BUTYLBENZENE (µg/L)	381	87	24	10	1.57	27	8.51
SELENIUM (µg/L)	769	195	19	17	1.5	53	7.96
SILVER (µg/L)	775	178	4	4	2.5	2.5	2.50
SPECIFIC CONDUCTANCE (UMHOS/CM)	273	167	273	167	6.8	9670	1151.72
STYRENE (µg/L)	853	205	2	2	0.52	0.57	0.55
SULFATE (AS SO4) ()			0	0	-	-	-
t-BUTYLBENZENE (µg/L)	382	87	22	8	1.4	18	4.13
TEMPERATURE (DEG C)	273	167	273	167	15.7	30.5	23.78
TERPHENYL-D14 (µg/L)	27	24	27	24	27	97	61.93
TETRACHLOROETHYLENE(PCE) (µg/L)	870	205	231	76	1	4200	114.52
THALLIUM (µg/L)	777	197	4	4	1	1	1.00
TOLUENE (µg/L)	904	205	29	18	1	111	11.22
TOLUENE-D8 (µg/L)	182	135	182	135	47.5	270	94.08
TOTAL 1,2-DICHLOROETHENE (µg/L)	456	178	131	69	1	350	37.92
TOTAL DISSOLVED SOLIDS (RESIDUE, FILTERABLE) ()			0	0	-	-	-
TOTAL ORGANIC CARBON ()			0	0	-	-	-
TOXAPHENE (µg/L)	345	157	0	0	-	-	-
trans-1,2-DICHLOROETHENE (µg/L)	415	116	12	9	0.76	32.7	7.76
trans-1,3-DICHLOROPROPENE (µg/L)	853	205	0	0	-	-	-
TRICHLOROETHYLENE (TCE) (µg/L)	877	205	391	108	1	1200	37.38
TRICHLOROFLUOROMETHANE (µg/L)	381	87	4	2	1.1	3.05	1.80
TURBIDITY (NTU)	7	7	7	7	2	29	11.86
VANADIUM (µg/L)	775	178	71	43	2.05	70	15.41
VINYL ACETATE (µg/L)	321	153	2	2	11	15	13.00
VINYL CHLORIDE (µg/L)	853	205	11	9	2	100	17.60
XYLENES, TOTAL (µg/L)	460	176	7	7	1	8200	1233.71
ZINC (µg/L)	775	178	163	95	3.07	554	54.17



LEGEND

- Zone Boundary
- Proposed Monitoring Well Location
- Propsode Soil Boring Location
- Proposed Station Inditification Number
- Existing Well Location

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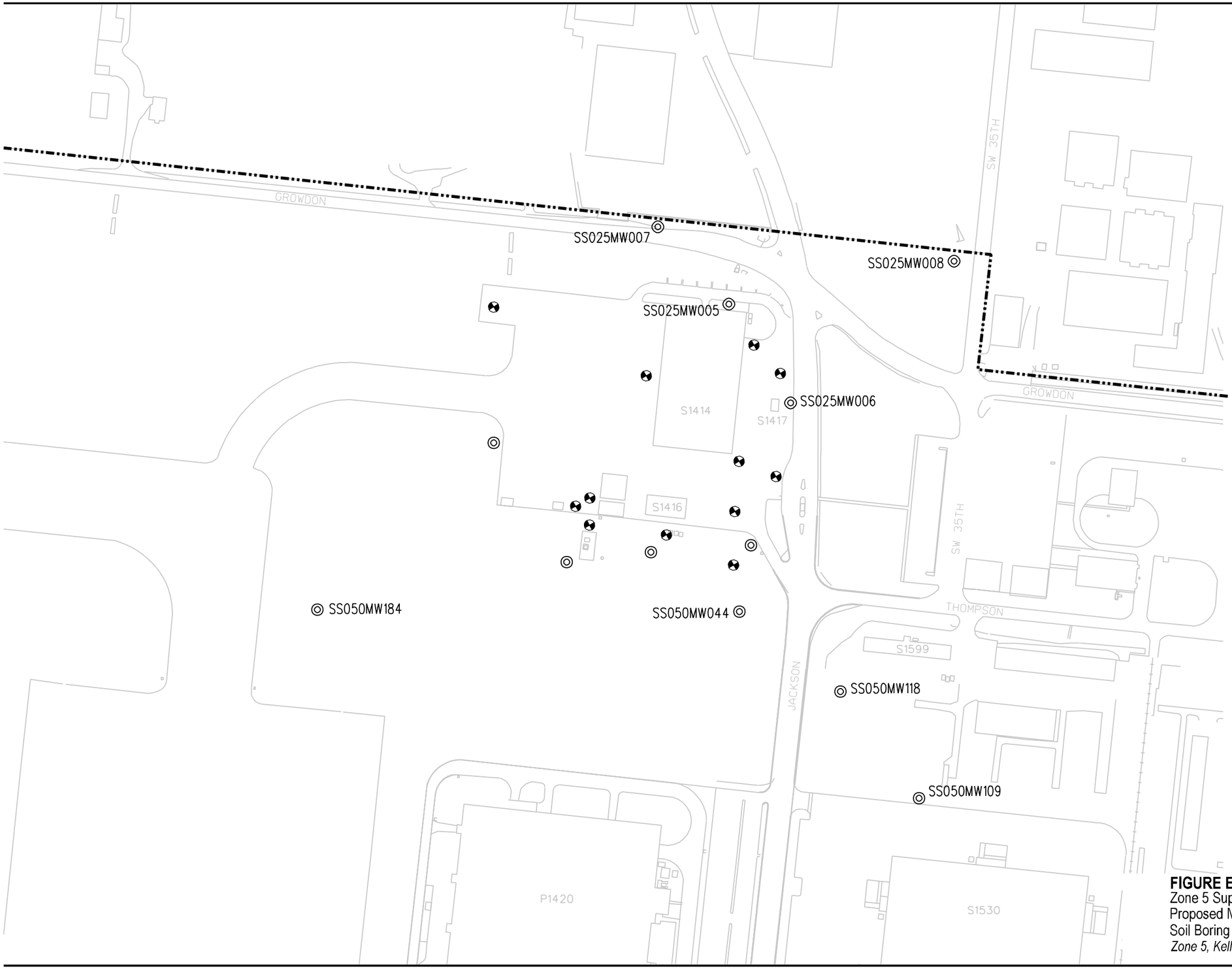
FIGURE E-2
Zone 5 Supplemental Characterization
Proposed Monitoring Well and
Soil Boring Locations, Site S-10
Zone 5, Kelly AFB, San Antonio, Texas

CH2MHILL



LEGEND

- Zone Boundary
- Proposed Monitoring Well Location
- Propsode Soil Boring Location
- Proposed Station Inditification Number
- Existing Well Location

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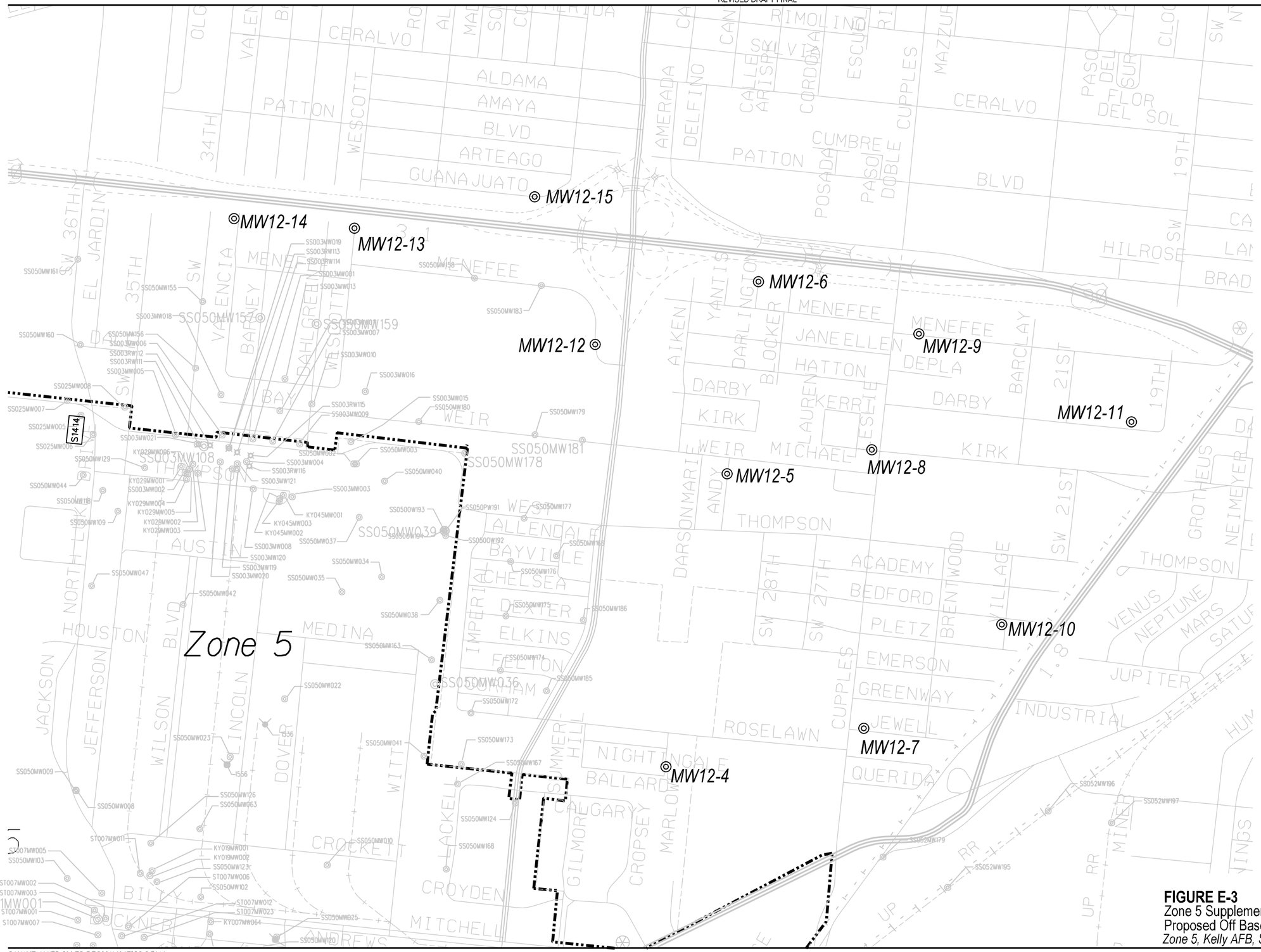
FIGURE E-1
Zone 5 Supplemental Characterization
Proposed Monitoring Well and
Soil Boring Locations Around Building 1414
Zone 5, Kelly AFB, San Antonio, Texas

CH2MHILL



LEGEND

- Off Base Monitoring Well Locations ◎
- Well Identification Number MW12-11
- Zone Boundary
- Existing Well Locations SS050MW179 ◎

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FIGURE E-3
Zone 5 Supplemental Characterization
Proposed Off Base Monitoring Well Locations
Zone 5, Kelly AFB, San Antonio, Texas

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17-DEC-1999

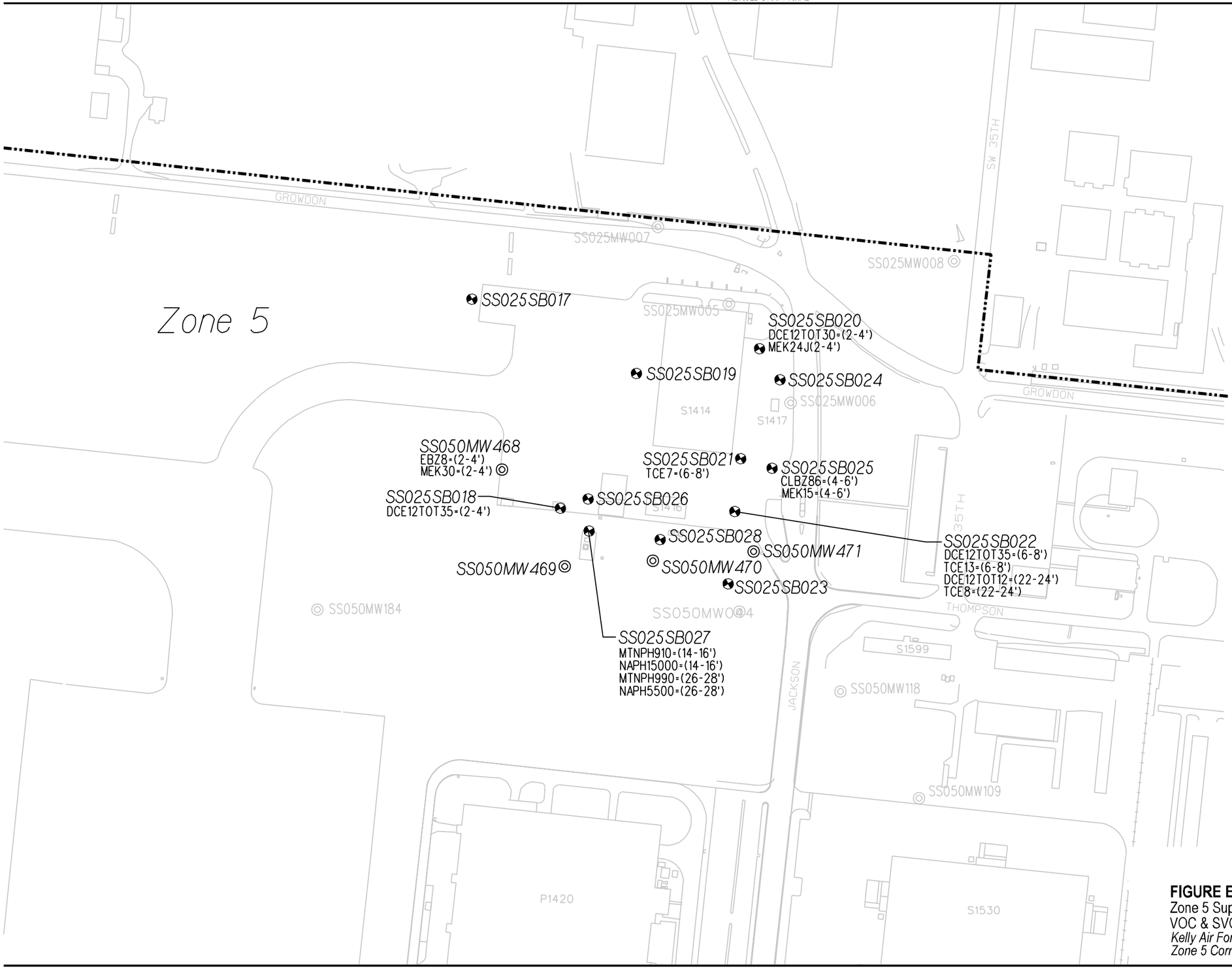

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FIGURE E-4
Zone 5 Supplemental Characterization
VOC & SVOC Soil Detections around Building 1414
Kelly Air Force Base
Zone 5 Corrective Measures Study-1998

CH2MHILL

SAN//KELLY/Z5-CM-FS-DEC99/1494FIG2-1A.DLV
21-DEC-1999

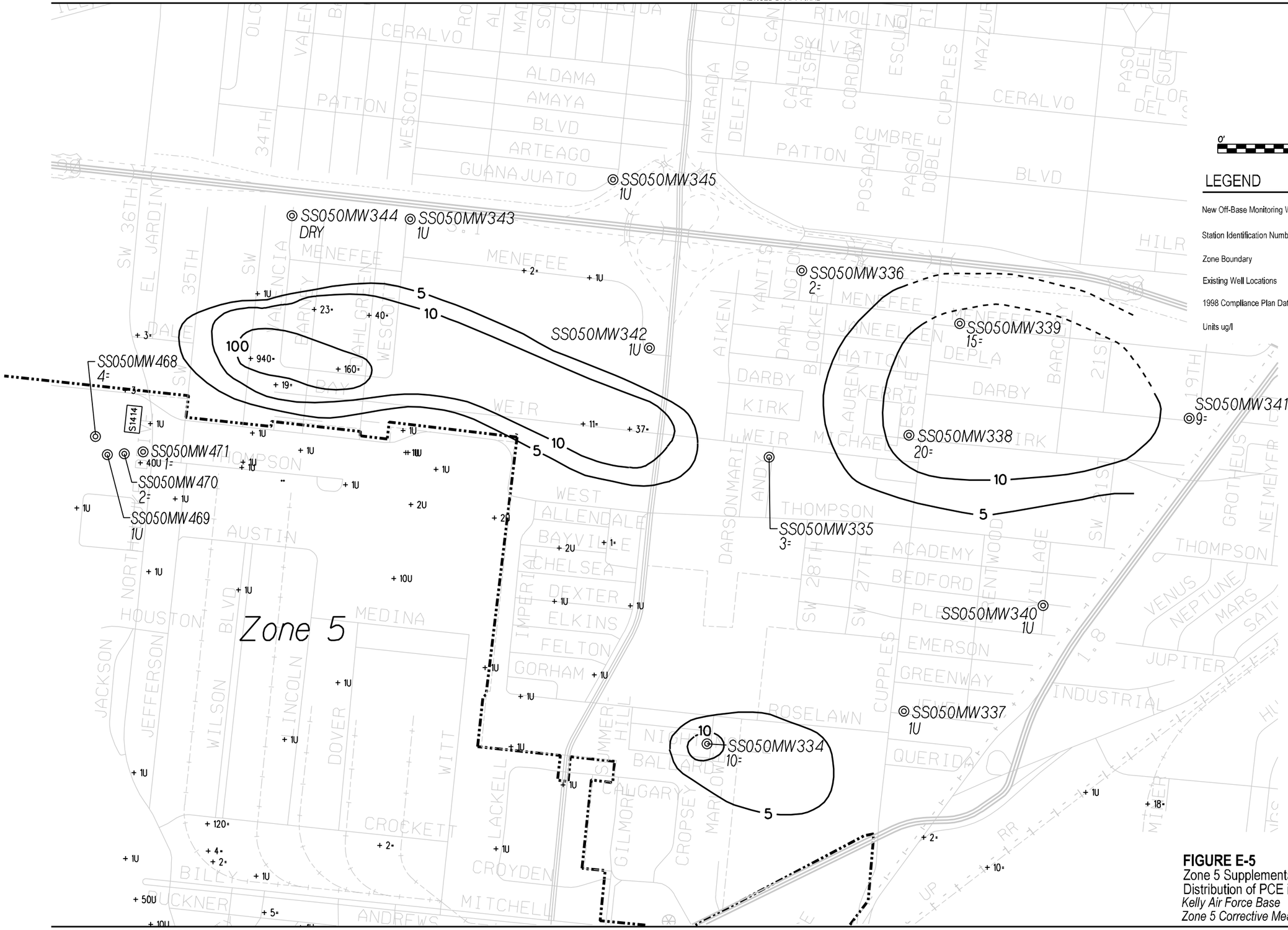

FIGURE E-5
Zone 5 Supplemental Characterization
Distribution of PCE in the Surficial Aquifer
Kelly Air Force Base
Zone 5 Corrective Measures Study-1998

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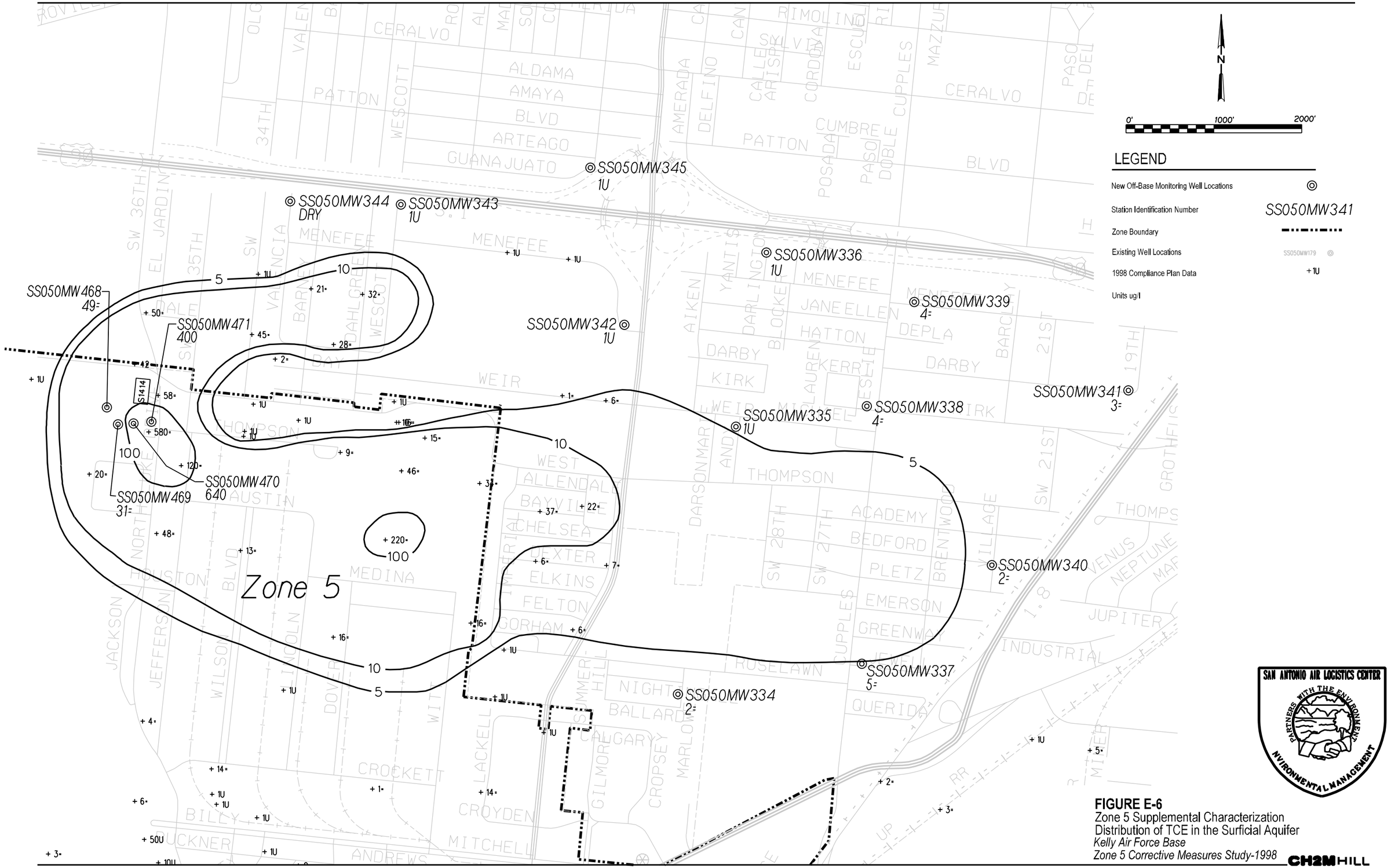

FIGURE E-6
Zone 5 Supplemental Characterization
Distribution of TCE in the Surficial Aquifer
Kelly Air Force Base
Zone 5 Corrective Measures Study-1998

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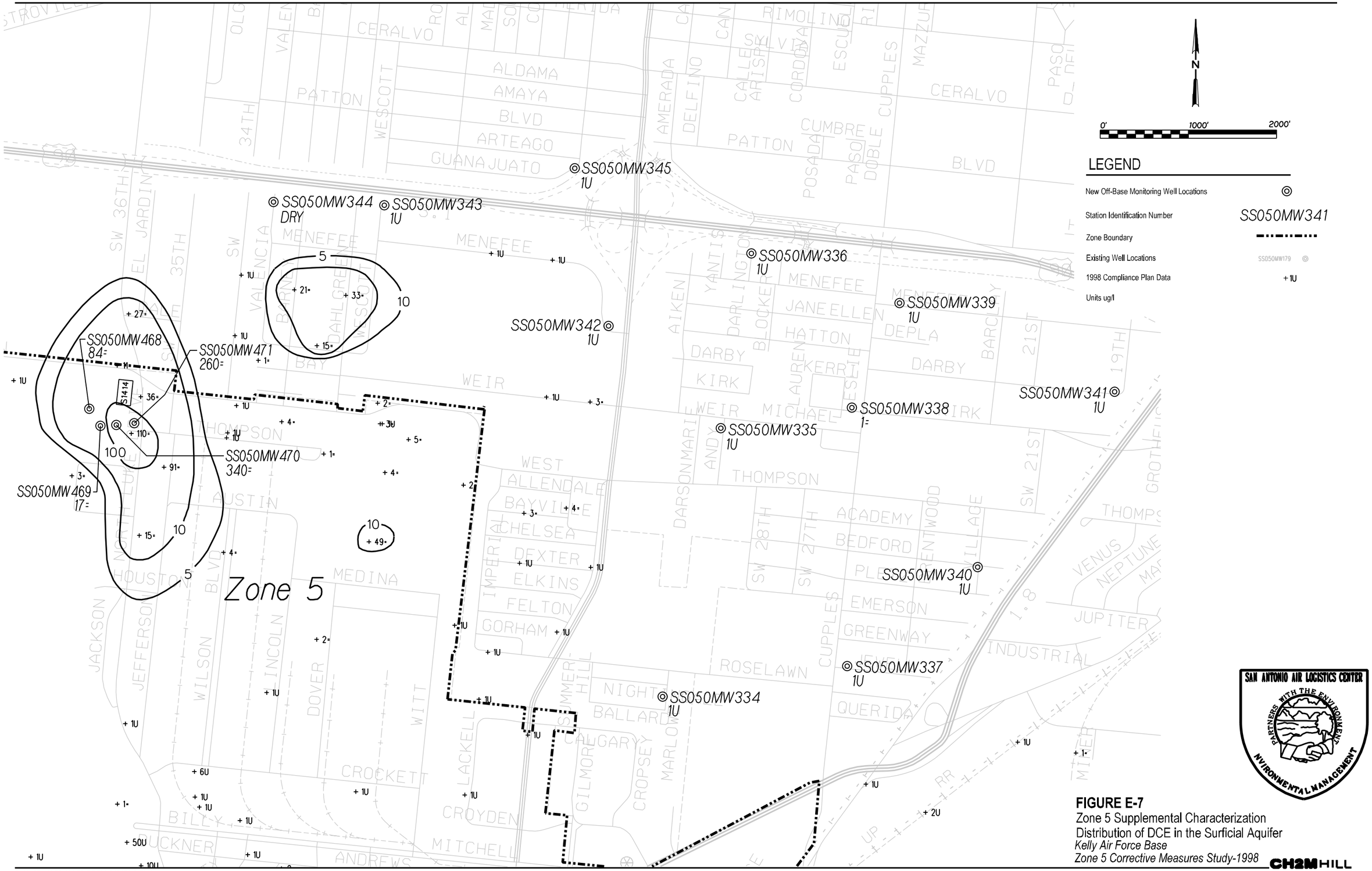

FIGURE E-7
Zone 5 Supplemental Characterization
Distribution of DCE in the Surficial Aquifer
Kelly Air Force Base
Zone 5 Corrective Measures Study-1998

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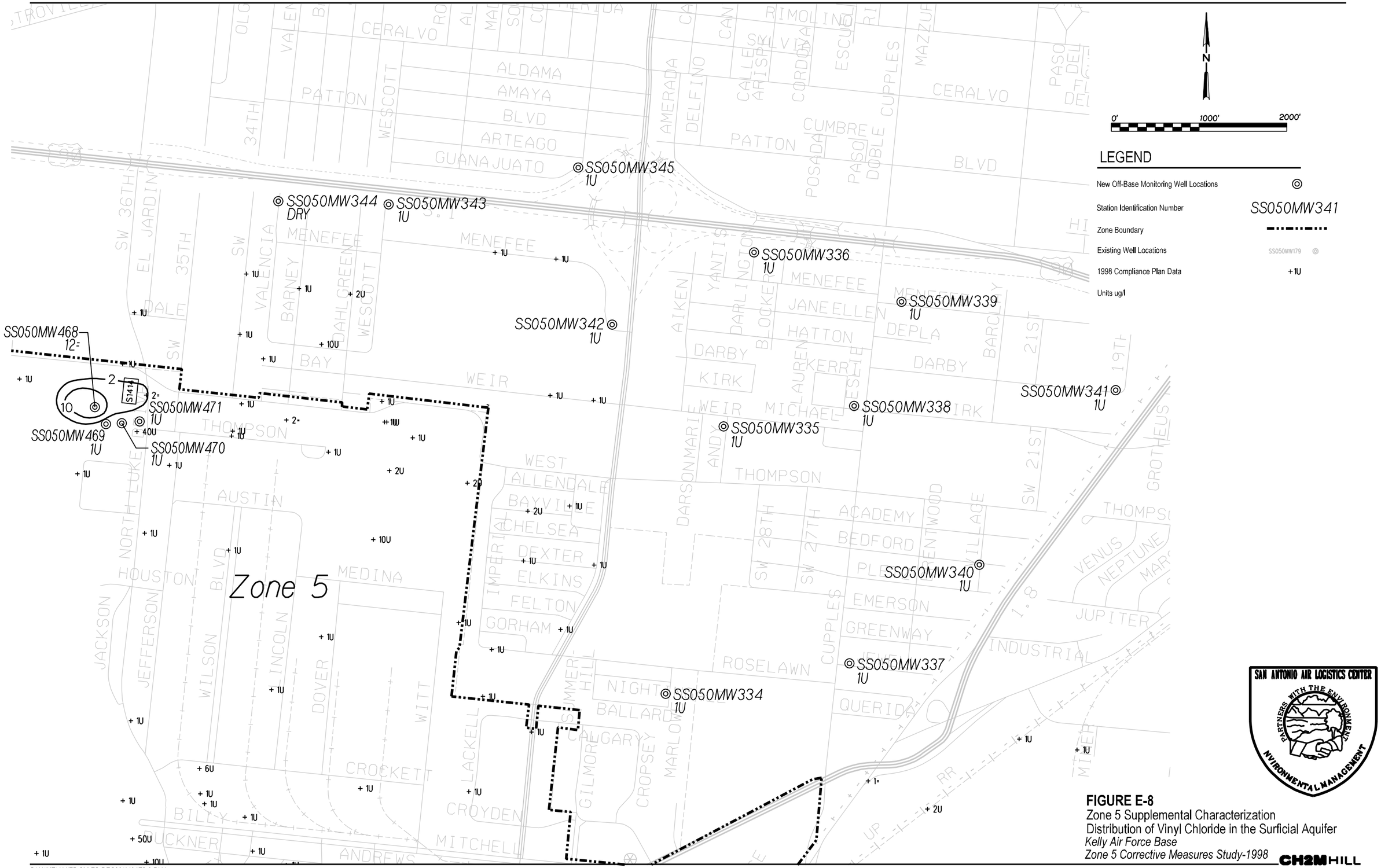

FIGURE E-8
Zone 5 Supplemental Characterization
Distribution of Vinyl Chloride in the Surficial Aquifer
Kelly Air Force Base
Zone 5 Corrective Measures Study-1998

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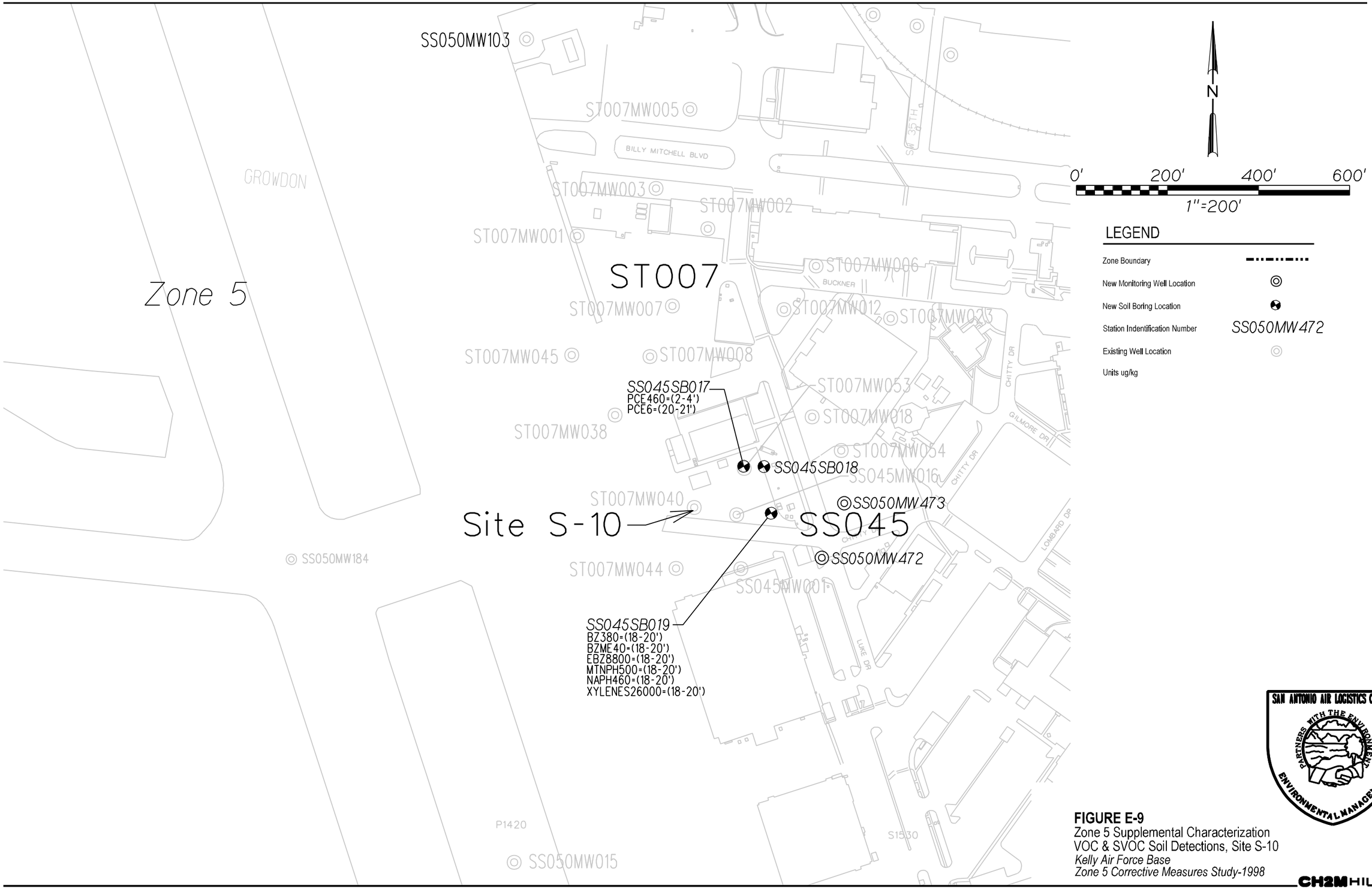

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FIGURE E-9
Zone 5 Supplemental Characterization
VOC & SVOC Soil Detections, Site S-10
Kelly Air Force Base
Zone 5 Corrective Measures Study-1998

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Appendix G

Groundwater Modeling Results

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Appendix G

Groundwater Modeling Results

Appendix G includes two independent groundwater flow and fate and transport modeling reports, done for the evaluation of remedial alternatives in Zone 5.

The first report presents preliminary flow and fate and transport modeling performed by CH2M HILL in the fall of 1998. This preliminary modeling includes a simplified fate and transport model which does not include biodegredation or decay rate parameters for PCE or TCE. A preliminary modeling simulation was performed for all plumes with exception of B, E, and K.

The second report presents more refined flow and fate and transport simulations by HydroGeoLogic in the fall of 1999. HydroGeoLogic's fate and transport simulations include an assessment of biodegredation potential based on groundwater geochemical parameters and decay rates for PCE, TCE, DCE, and vinyl chloride. HydroGeoLogic's modeling includes simulations for plumes A, D, G, H, and J.

The following table summarizes the Zone 5 groundwater plume modeling.

Plume	A	B	C	D	E	F	G	H	I	J	K
CH2M HILL	Yes			Yes		Yes	Yes	Yes	Yes	Yes	
HGL	Yes			Yes			Yes	Yes		Yes	

Results for Fate and Transport and Flow Modeling

1.0 Conceptual Site Model

1.1 Groundwater

Shallow groundwater beneath Kelly Air Force Base (AFB) is present in alluvial sediments that overlie the Navarro Group clay aquitard. The aquifer occurs within alluvial sediments that tend to fine vertically from a coarse gravel and sand sequence to silt, clay, and fill material near land surface. The basal gravel ranges in thickness from 1 to 32 ft, but generally extends 10 to 20 ft above the upper Navarro Group surface. The saturated thickness ranges from approximately 0 to 30 ft across Zone 5, with the average being less than 10 ft. Groundwater flow in the gravel unit is approximately horizontal and under unconfined conditions. However, semi-confined conditions exist in the southeastern portion of Zone 5, along the boundary with Zone 3, where the basal gravel zone is less than 10 ft thick.

The Navarro clay serves as a barrier to groundwater flow. The Navarro Group severely restricts downward migration of alluvial groundwater and represents the lower boundary of the aquifer system. Lateral aquifer boundaries are defined where the clay surface emerges above the water table. This condition is most prevalent in the northern portion of Zone 5. Some areas of the northern part of Zone 5 are dry for parts of the year.

The irregular topography of the upper Navarro Group (refer to Figure 2.4 in this Corrective Measures Study [CMS] report) controls shallow groundwater flow throughout Kelly AFB. The potentiometric surface in the shallow aquifer reflects both the upper Navarro Group and the ground surface topography. Groundwater flow is radially away from a potentiometric high in the north part of Zone 5. The potentiometric high corresponds to a ridge in the Navarro Group surface.

Hydraulic conductivity values for the alluvial aquifer in Zone 5, based on slug and pumping test results, range from about 0.2 to over 400 ft/day. Hydraulic conductivity is highest near the north Zone 5 boundary, east of the potentiometric high, and to the south along the boundary with Zone 2.

1.2 Contaminants and Areas of Concern

The remedial investigation (RI) and the feasibility study (FS) data evaluation identified benzene, chlorobenzene, tetrachloroethene (PCE), trichloroethene (TCE), and total 1,2-dichloroethene (1,2-DCE) as primary chemicals of concern. The RI presents the distribution and extent of these organic compounds in the groundwater and identified the areas to be addressed in this CMS report. Figure 3.15 (this report) shows the locations and designations of each of the contaminant plumes. Eight of the eleven groundwater plume areas are addressed in the modeling of the Zone 5 remedial alternatives (this appendix).

1.2.1 Plumes A, B, and H

These plumes are located in the general area of the former solvent still SS025 (IS-1), site SS003 (S-1), and the off base areas north and northeast of the base. Contaminants of concern in this area include TCE, 1,2-DCE, and PCE.

Plume A includes a maximum concentration of TCE (1,200 µg/L) detected at monitoring well SS050MW118, southeast of the presumed location of the IS-1 spill. Plume A extends approximately 1,200 ft north, 6,200 ft east, and 7,500 ft to the south of the IS-1 site. The portion of this plume that has migrated beneath the runway is designated as Plume H. The eastern extent of the plume extends off base and has not been fully defined. Plume A also encompasses a small 1,2-DCE (exceeding 70 µg/L) plume that extends about 1,500 ft in a north-south orientation. The maximum 1,2-DCE concentration (320 µg/L) was also measured in well SS050MW118, potentially indicating biodegradation of TCE.

Plume B includes PCE, TCE, and DCE. It is located just north of the base and extends about 4,000 ft in a west-to-east orientation along the local groundwater flow path. The maximum concentration of PCE in this plume was 2,600 µg/L in SS050MW156, which is located 650 ft directly north of the base. As discussed in the RI, the source of this plume does not appear to be related to Kelly AFB.

1.2.2 Plumes D, F, and G

Plume D includes small, isolated PCE, TCE, and benzene plumes. The PCE-contaminated area is defined by four wells (SS050MW126, SS050MW123, SS050MW062, and ST007MW053) with elevated PCE concentrations. The maximum PCE concentration (4,200 µg/L) was detected in ST007MW053.

Plume D TCE distribution is located south of the PCE plume. TCE concentrations exceeding 5 µg/L were detected in four monitoring wells (SS050MW120, KY041MW001, KY041MW003 and SS050MW113) with a maximum concentration of 240 µg/L in monitoring well SS050MW113. The plume extends about 1,200 ft in an east-west direction.

Plume F is southeast of Plume D and contains very low concentrations of PCE (up to 9 µg/L)

Plume G is defined by elevated benzene concentrations which appear to be related to the ST007 (S-5) and SS045 (S-10) Spill Areas. The maximum benzene concentration (150 µg/L) was measured in well ST007MW001, located about 50 ft west of the ST007 (S-5) Spill Area. Plume G may also contain solvent constituents from Plume D.

1.2.3 Plume I

Plume I contains relatively large PCE, TCE and 1,2-DCE concentrations in the southern portion of the runway area. As discussed in the 1997 draft RI, there is no known source of PCE or TCE in this area and the plume appears to be contiguous with solvent plumes observed in Zone 3. The TCE and 1,2-DCE plumes are likely associated with degradation of PCE. The maximum concentrations of PCE (1,300 µg/L), TCE (79 µg/L) and 1,2-DCE (290 µg/L) were all detected in monitoring well SS050MW106, located about 1,600 ft west of the boundary between Zone 5 and Zone 3.

1.2.4 Plume J

Plume J is a co-mingled PCE/TCE plume. Plume J extends approximately 2,000 ft in a north-south orientation. The maximum concentrations of PCE (120 µg/L) and TCE (8 µg/L) were measured in KY028MW006 and KY028MW031, respectively.

2.0 Basewide Flow Model

The 1996 Basewide Groundwater Flow Model (CH2M HILL, 1998) encompasses most of Kelly AFB and includes all of Zone 5. It serves as the basis for all flow and fate and transport modeling in Zone 5. The basewide model, constructed using the U.S. Geological Survey MODFLOW (McDonald and Harbaugh, 1988) computer model, provides a simplified representation of the complex hydrogeologic framework at Kelly AFB. The two predominant strata at the base are the clayey surface strata and the deeper alluvium, which comprises the surficial aquifer beneath Kelly AFB. The corresponding 2-layer model generally reflects the dramatic variations in aquifer characteristics that are evident at the base.

The hydraulic conductivity of the alluvial aquifer was initially established using primarily slug test results as an indicator. The hydraulic conductivity distribution is referenced from the *Kelly AFB 1996 Basewide Remedial Assessment, Basewide Groundwater Flow Model Report,* published in May of 1998. Limited pumping test data was weighted more heavily in development of the hydraulic conductivity distribution that was later refined during calibration. The March 1996 measured potentiometric surface served as the basis for evaluating model calibration. Basewide recharge was established at 2 in./yr for the March 1996 period. Average basewide recharge is estimated at 3 in./yr.

Average annual conditions were simulated by replacing the March 1996 potentiometric surface and groundwater withdrawal rates with values more representative of long-term conditions. The synthesized 1994 average annual potentiometric surface and average withdrawal rates were used to evaluate long-term conditions. The simulated groundwater flow field that resulted from this average annual simulation was the input basis for the Zone 5 fate and transport modeling.

The fate and transport modeling was based on a steady state simulation output from the Basewide Flow Model with the existing recovery systems in operation. However, the effects of these systems on the basewide flow patterns in a steady state simulation are negligible. The hydraulic influence of the recovery wells/trenches is highly localized, extending less than 200 ft from each system. In addition, the recovery systems are located on the perimeter of the base and serve to only to intercept local groundwater flow not redirect the groundwater gradient or accelerate groundwater flow. The saturated thickness of the aquifer and groundwater recovery rates are insufficient to create a substantial change in groundwater gradients or flow velocities. Exhibit G.1 shows two sets of head contours based on steady state simulations of the basewide flow model. One simulation was run with the recovery systems in operation and the other was run with the recovery systems not in operation the resulting head contours confirm that the recovery system operation has little to no impact on groundwater velocities or flow gradients. The only variation occurs in the vicinity of the S-8 recovery system in Zone 3. Therefore steady state simulation of the

recovery systems in the basewide flow model has no meaningful effect on the direction or speed of plume migration simulated in the models.

3.0 Basewide Fate and Transport Model

The fate and transport of contaminants of concern in Zone 5 was modeled using the MT3D solute transport model (Zheng, 1990). MT3D is a modular three-dimensional transport model for the simulation of advection, dispersion and chemical reactions of dissolved constituents in groundwater. MT3D is divided into a series of different components or "packages" (Table G.1), which provide computational flexibility.

The transport model uses the head distribution and cell-by-cell flux computed by the MODFLOW model to define the flow field for the contaminant transport. The model allows for a constant source or an existing contaminant distribution to be imported as the initial concentrations for the simulation. The calculated results of the transport model are the contaminant concentrations and distributions at specified time intervals.

4.0 Fate and Transport Simulations

The available data on plume age, initial contaminant mass, and exact source location for the TCE and PCE plumes at Kelly AFB is incomplete. In addition, Although basewide contaminant data has been collected and contoured annually from 1994 to 1998, it is impossible to use this data for the purposes of plume calibration.

First, the number of monitoring well used to delineate groundwater contamination has increased substantially over the past four years. One of the primary purposes for the installation of new monitoring wells under various projects was to more accurately define the nature and extent of groundwater contamination. As a result, the actual extent of many plumes was not/has not been fully defined. The full extent of some plumes is still undetermined.

Second, the same set of wells is not sampled from year to year. Although some wells are re-sampled consistently many wells are switched out from year to year. As a result the extent of plume contours often varies as the result of the data set, not because of contaminant movement.

Third, each year new wells are installed and sampled and add to the available set of contoured data. As a result, it is difficult to accurately evaluate variations in plume contours, especially those occurring along the leading edge where the full extent of contamination may not be well defined. In addition, in many areas, groundwater velocities are very low in relation to well density. As a result, in many areas the down gradient well density is not sufficient to accurately document contaminant migration on a scale as small as 4 years.

Finally, even data collected yearly from the same well is subject to variations that may be the result of water table fluctuations rather than movement of contaminant mass. Contaminants trapped in the vadose zone are a known source of groundwater contamination.

As a result of the lack of historical spill information and the changes in available analytical data, it was not technically possible to "calibrate" the MT3D fate and transport model. Instead, the capability of the model to simulate mapped contaminant distributions was demonstrated using measured data, mapped analyte distributions, and reasonable parameter estimates based on general assumptions.

Contaminant degradation was not modeled because insufficient data is available to determine degradation rates. In general, the degradation rates of the chlorinated volatile organic compounds (VOCs) in the aerobic portions of the plumes modeled are expected to be relatively slow. Kelly AFB is currently pursuing a study to determine degradation rates and model natural attenuation basewide. That more detailed study may result in revisions to the results presented in this Zone 5 remedial alternative evaluation. It is expected that the results presented here are conservative estimates of natural attenuation.

4.1 Model Setup

Layer 1 was simulated as unconfined and layer 2 was simulated as confined. The thickness of layer 1 was calculated as the difference between the potentiometric surface elevation and the elevation of the bottom of layer 1. The thickness of layer 2 was calculated as the difference between the potentiometric surface elevation and the bottom of layer 2 or the difference between the top of layer 2 and the bottom of layer 2, whichever value was less. Layer 2 thickness was calculated in this manner to maintain an accurate calculation of aquifer thickness in partially confined areas. The top of layer 1 was arbitrarily calculated to be 10 ft above the potentiometric surface elevation. Effective porosity values of 0.4 and 0.2 were assigned to layer 1 and layer 2 respectively.

4.2 TCE Simulations

The following inputs were used for the MT3D simulation of TCE:

- Advection was simulated using a hybrid of Method of Characteristics and Modified Method of Characteristics solution schemes.
- Tracking Algorithm defined for the Method of Characteristics scheme is fourth order Runge-Kutta at or near sources and first order Euler elsewhere.
- Concentration weighting factor was set at 0.5.
- Particles were placed randomly in cells, 16 particles per cell.
- Longitudinal dispersivity = 50.
- Ratio of longitudinal to transverse dispersivity = 0.1.
- Ratio of vertical dispersivity to longitudinal = 1.0×10^{-5} (negligible).
- Effective Molecular Diffusion Coefficient = 0.
- No point sources or sinks were initialized.
- Linear sorption was simulated with the chemical reaction package.
- Bulk Density = 1.73 g/cm^3 (average of values measured in the Zone 5 RI soil samples).

- Fraction of organic carbon (foc) = 3.82×10^{-4}, based on an average of the low range (382 mg/kg) of total organic carbon measured in the Zone 5 RI soil samples. Soil analyses from the Zone 5 RI soil samples revealed no obvious or consistent trend in foc values in relation to depth or strata sampled. Therefore the same value was used for layers 1 and 2 in the model. In addition, the majority of layer 1 is unsaturated and thus inactivated in the model. In the few areas where parts of layer 1 are active, the flow is minimal due to the low hydraulic conductivity value (0.2 ft/day) and thus contributes negligibly to plume movement. The majority of significant contaminant transport occurs in layer 2.
- Partition Coefficient (Koc) = 126 cm^3/g, from Zone 5 RI appendix "properties of organic chemicals."
- Distribution Coefficient (Kd) = Koc x foc = $126 \times 3.82 \times 10^{-4} = 0.048$ cm^3/g.
- Based on a Zone 5 TCE analyte distribution map, a constant source of 500µg/L was simulated in a five cell north-south linear array just west of monitoring well SS050MW118.
- With the exception of source concentrations, all transport-related input were the same for layer 1 and 2. Sources were only input into layer 2.

Plume A was selected to observe the models capability to simulate the fate and transport of TCE. MT3D simulations of Plume A approximate the mapped TCE plume after approximately 30 years. The contaminant distributions and concentrations are generally consistent with the mapped plume at this time. Since the possible source, the SS025 (IS-1) solvent still, operated between 1955 and 1972, a plume age of 30 years is reasonable (Exhibit G.2).

4.3 PCE Simulations

The following inputs were used for the MT3D simulation of PCE:

- Advection was simulated using a hybrid of Method of Characteristics and Modified Method of Characteristics.
- Tracking Algorithm defined for the Method of Characteristics solution scheme was fourth order Runge-Kutta at or near sources and first order Euler elsewhere.
- Concentration weighting factor was set at 0.5.
- Particles were placed randomly in cells, 16 particles per cell.
- Longitudinal dispersivity = 50.
- Ratio of transverse to longitudinal dispersivity = 0.3.
- Ratio of longitudinal to vertical dispersivity = 1.0×10^{-5} (negligible).
- Effective Molecular Diffusion Coefficient = 0.
- No point sources or sinks were initialized.

- Linear sorption was simulated with the chemical reaction package.
- Bulk Density = 1.73 g/cm^3 (average of values measured in the Zone 5 RI soil samples).
- Fraction of organic carbon (foc) = 3.82x10-4 , based on an average of the low range (382 mg/kg) of total organic carbon measured in the Zone 5 RI soil samples Soil analyses from the Zone 5 RI soil samples revealed no obvious or consistent trend in foc values in relation to depth or strata sampled. Therefore the same value was used for layers 1 and 2 in the model. In addition, the majority of layer 1 is unsaturated and thus inactivated in the model. In the few areas where parts of layer 1 are active, the flow is minimal due to the low hydraulic conductivity value (0.2 ft/day) and thus contributes negligibly to plume movement. The majority of significant contaminant transport occurs in layer 2.
- Partition Coefficient (Koc) = 364 cm^3/g from Zone 5 RI appendix "properties of organic chemicals."
- Distribution Coefficient (Kd) = Koc x foc = 364 x 3.82x10-4 = 0.139 cm^3/g.
- Based on the Zone 5 PCE analyte distribution map, a constant source of 1,000 µg/L was simulated in one cell which corresponds to the location of monitoring well SS050MW156.
- With the exception of source concentrations, all transport-related input were the same for layer 1 and 2. Sources were only input into layer 2.

Plume B was selected to evaluate the model's capability to simulate PCE distributions at Kelly. MT3D simulations of Plume B approach mapped concentrations of PCE at approximately 10 years (Exhibit G.3). The exact age and source mass of this plume is unknown.

4.4 Simulation Results

The results of these TCE and PCE simulations confirmed the general application of both the basewide flow model and the MT3D fate and transport simulations as a tool for evaluating remedial alternatives. The input values have not been "calibrated", but are within the range of values that result in simulated contaminant distributions that are similar to mapped field data.

A constant value for longitudinal dispersivity was used for all PCE and TCE simulations. Because dispersivity is a scale dependant material property the actual dispersivity values for the smaller plumes will be smaller that that of the larger plumes. However, there are no measured values (range or average) for dispersivity in the Kelly aquifer, and without historical knowledge of the approximate age of the smaller plumes, a scaled reduction of the dispersivity and its resulting effects on plume development would be arbitrary. As a result the longitudinal dispersivity was held constant in all of the simulations.

A ratio of transverse to longitudinal dispersivity that resulted in the best match between the measured and simulated plumes was selected for TCE and PCE. The fact that the ratio that produced the best simulated plume match were different for TCE (0.1) and PCE (0.3) reflects the heterogeneity of the aquifer material not the behavior of the contaminant. For consistency, these values were carried over to the subsequent simulations of TCE and PCE

plumes. The actual ratio of transverse to longitudinal dispersivity is probably somewhere between 0.1 and 0.3.

In general, source concentrations simulated with the model are less than those measured in the field. The differences between modeled and actual source concentrations result from the minimum source area being limited to the 200 by 200 ft model cell size. In addition, the source mass is simulated as infinitely constant when in actuality it is probably declining. A declining source mass is not simulated by MT3D. MT3D also cannot account for degradation to daughter products such as DCE and vinyl chloride. As a result, TCE and PCE are simulated separately to account for the differences in their partition coefficients. 1,2-DCE was not modeled because its concentrations are lower than TCE, its distribution is accounted for within the TCE plumes location, and its partition coefficient is less than half that of TCE.

4.5 Other Zone 5 Contaminants

Separate fate and transport model simulations were not run for DCE because it generally occurs in the same areas as the TCE and PCE, but at lower concentrations and smaller areal distribution. In addition, because its distribution coefficient is lower that that of TCE and PCE, its retardation factor is lower and its concentrations disperse more rapidly.

Neither benzene nor chlorobenzene was simulated with the MT3D fate and transport model because the biodegradation rate for these chemicals is controlled by electron acceptor availability that is not calculated by MT3D.

5.0 Flow Modeling in Support of Alternative Development

The Basewide Flow Model described previously was used to generate four refined scale groundwater flow models for Zone 5, (north, south, east , and west study areas) and one refined scale model for Zone 2. The refined scale grids allowed for the modeling of groundwater collection systems and simulation of recovery of groundwater contaminant plumes either at the source or at the downgradient edge. The objective of this modeling was to establish preliminary estimates of the locations, numbers, and flow rates for extraction wells or trenches that would be required to intercept the plumes.

5.1 Development of Refined Flow Models

Model input developed for the average annual basewide model was translated electronically to the Zone 5 and Zone 2 refined scale models. A total of five refined flow models were created; four for Zone 5, North Study Area (NSA), South Study Area (SSA), East Study Area (ESA) and West Study Area (WSA); and one for Zone 2. Model input developed for the average annual basewide model was translated electronically to each of the refined area models. The refined flow models were used for all recovery system evaluations.

Each refined scale model was created from the basewide model data sets. The four Zone 5 subset models were created with 40 by 40 ft grid spacing. The Zone 2 subset model, because of the relatively thin saturated thickness and steep hydraulic gradient, was created using 20 by 20 ft grid spacing. Table G.2 summarizes characteristics for the basewide and five subset

flow models. Horizontal discretization parameters include the number of rows, number of columns, and grid spacing. The range of alluvial thickness, calibrated hydraulic conductivity, and Navarro Group elevation are also listed in Table G.2.

The simulated average annual groundwater flux in the basewide model is reproduced in each refined area model. Model boundaries are uniformly established as constant-head condition, which allows flux into or out of the model. Starting heads are those simulated in the basewide average annual model. All data sets, including the elevations of each layer, hydraulic conductivity, and recharge were extracted from the basewide model grid then re-interpolated to the refined area subset grids. The limits of each area grid and the output heads of the active refined area models are superimposed on the output heads for the basewide grid to confirm the accuracy of the data translation (Exhibit G.4).

The limits and output heads of the active NSA, ESA, SSA, WSA, and Zone 2 model areas respective to the basewide model grid are shown in Exhibits G.4, G.5, G.6, G.7, and G.8.

6.0 Model Grid Scale Evaluation for Fate and Transport Simulations

To evaluate the sensitivity of the fate and transport model to grid scale, the simulated results of Plume B were evaluated using both the basewide model grid (200 by 200 ft) and the NSA refined model grid. The refined model grid was created as a subset of the basewide grid, but with 40 by 40 ft grid spacing (see Section 5.1). The finer grid of the NSA model increases the resolution for equations used to calculate the fate and transport of contaminants. The area covered by the refined grid is limited in order to minimize computational requirements.

The input parameters for the fate and transport simulation of Plume B (PCE) were the same as the simulation executed with the basewide model. A constant concentration of 1,000 µg/L was input as the source mass in a 200 by 200 ft area (25 cells in the refined grid). All other input variables were identical to those used in the basewide model simulation. The simulation was then run for 15 years and the results compared with the output for the same simulation conducted using the 200 by 200 ft basewide grid.

Exhibit G.9 shows the calculated concentration contours from the NSA grid overlaid on the concentration contours of the basewide grid. The resulting concentration distributions are equivalent. The results of these two simulations suggest that the relative accuracy of the fate and transport simulations were not compromised by the 200 by 200 ft basewide grid scale.

7.0 Remedial Alternative Evaluation

The remedial alternative evaluation for each plume is prefaced with a description of the known contaminant distribution and approximate age and source conditions estimated from fate and transport simulations.

Numerous remedial alternatives are available for each plume. The following alternatives were simulated using both the flow and the fate and transport models. Not all alternatives were simulated for each plume. The simulated alternatives are defined as follows:

Source Control - Simulating a recovery system that will remediate the area of groundwater within the plume with the highest contaminant concentration.

Natural Attenuation - Simulating the natural degradation and movement of an existing plume whose source is or has been remediated.

Steady State - Simulating the natural degradation and movement of a plume with a continuing source (i.e., natural attenuation without source control).

Downgradient Perimeter Control - Simulating a recovery system that will intercept a plume at its leading or downgradient edge (on or off base). Estimated durations for operation of these remedial systems is based on the assumption that there is no addition of source mass to the plume (i.e., source control).

Perimeter Control at the Base Boundary - Simulating a recovery system that will intercept a plume at the base boundary irrespective of whether or not that corresponds to the leading edge of the plume. Estimated durations for operation of these remedial systems pertains only to the portion of the plume upgradient of the recovery system and is based on the assumption that there is no addition of source mass to the plume (i.e., source control)

Off base Recovery - Simulating a remedial system that will recover off base portions of the plume irrespective of the plumes extent or leading edge.

Downgradient Perimeter Control with Upgradient Injection Wells - Simulating injection wells designed to supplementing the downgradient perimeter control recovery system by reinjecting treated water at the upgradient or trailing edge of the plume. Estimated durations for operation of these remedial systems is based on the assumption that there is no addition of source mass to the plume (i.e., source control)

7.1 Plumes A and H

7.1.1 TCE Contaminant Distribution

Based on historical information and field sample data, the source of the TCE in Plume A is probably soils receiving releases from the solvent still at site IS-1 or the sewers adjacent to Building 1414. Simulations of TCE in this area suggest that a constant source, equivalent to 500 μg/L in a line approximately 1,000 ft in length, over a period of approximately 30 years would be required to produce the current contaminant distribution (Exhibit G.2). Measured concentrations of TCE in the source area range from 480 to 1,200 μg/L. However, this source mass is probably declining rather than constant. Since the model cannot simulate a declining source, a constant source of lower contaminant mass must be used to simulate the current distribution. The total source mass in the model simulation is approximately equivalent to 1.23 lbs. (0.1 gal)/year. Given the solvent still operation dates from 1955 to 1972, an approximate plume age of 30 years is reasonable. In addition, simulations suggest that historical releases from the IS-1 solvent still or adjacent sewers into the soils may also be the source of Plume H. Because there is little groundwater data between the solvent still site and Plume H, it is not possible to confirm or eliminate the solvent still or sewers as a possible source location. However, model simulations suggest that groundwater flow could carry TCE in the southwest direction from the SS025 (IS-1) site.

One possible source mechanism for Plume H is related to seasonal changes in groundwater levels. When the groundwater elevations are high, groundwater could come in contact with residual TCE source trapped in the unsaturated zone. When groundwater elevations drop, the finite TCE concentrations that were leached from the soil are carried with the groundwater flow to the southwest. At lower elevations, the groundwater may not be in continuous contact with the TCE source, resulting in small, discrete plumes.

7.1.2 Plume A: Source Control and Natural Attenuation

A recovery trench was simulated for source control via pump and treat for Plume A. A trench recovery system is applicable in this area because of the thin saturated thickness and relatively shallow depth to Navarro. Exhibit G.10 shows the simulated locations of the recovery trench and its simulated capture zone. The simulated trench section is approximately 1,000 ft in length and is located to intercept the highest concentrations of PCE and DCE in Plume A. Simulated recovery from the trench is 17 gpm. Control head elevations in each trench section are 2 to 3 ft below the static potentiometric surface.

Assuming effective source control, the fate and transport of the remaining TCE contaminant concentration in Plume A was simulated by removing the constant concentration of TCE from the model simulations. The existing TCE distribution was input into the model as the starting concentration. The simulation was then run until the initial concentration had dropped below 5 μg/L (the MCL for TCE).

The results of the simulation suggest that if the source mass were eliminated/controlled, approximately 25 years would be required for the current contaminant distribution to decrease to 5 μg/L on-base (Exhibit G.11).

7.1.3 Plume A: Perimeter Control at the Base Boundary and Natural Attenuation

Base boundary perimeter control for Plume A was simulated with two types of remedial systems. One simulation was run using a recovery trench and a second simulation was run using recovery wells. The modeled recovery trench length is approximately 3,000 ft. The control head was set at 3 ft below the static potentiometric surface. Full capture was simulated from the trench at a total flow of approximately 50 gpm (Exhibit G.12).

Perimeter control for the same location was also simulated using recovery wells. Seven recovery wells approximately 400 ft apart were modeled. Full capture was simulated with a total recovery rate of 50 gpm (Exhibit G.13).

With perimeter control at the base boundary, fate and transport simulations for the portion of Plume A that is currently off base, but within the model domain (approximately 1,500 ft east of the base boundary), would require 10 years to reach 5 μg/L. (Exhibit G.14).

7.1.4 Plume A: Off base Recovery Systems

Off base recovery and treatment for Plume A was simulated using 12 recovery wells approximately 400 ft apart. Recovery wells were pumping 3 to 5 gpm each for a total system recovery of approximately 50 gpm (Exhibit G-15).

The off base and perimeter control recovery systems (Section 7.1.3 of this appendix) could not be modeled simultaneously due to the proximity of the recovery systems to the model

boundary. Although it could not be modeled, effective recovery of groundwater at the base boundary (perimeter control) will limit the flow available for capture by the down-gradient, off base recovery wells. The extent of this effect cannot be predicted with the existing model. However, the further the off base recovery wells are from the perimeter recovery system, the less effect the perimeter system will have on the total flux captured by the off base wells.

The time required for operation of the off base recovery wells is undetermined because the extent of off base contamination is unknown and the effect of a perimeter control system on the off base system cannot be accurately simulated.

The actual recovery rates, number of recovery wells, well spacing and trench lengths required for full source control, perimeter control and/or off base recovery of Plume A may vary from those simulated in the models.

7.1.5 Plume H: Downgradient Perimeter Control

Downgradient perimeter control for Plume H was modeled using recovery wells. Eight recovery wells are simulated approximately 175 ft apart along the downgradient edge of the plume. Each recovery well is pumping 10 gpm for a total system recovery rate of 80 gpm. Full capture is simulated at this recovery rate (Exhibit G.16).

Fate and transport simulations of Plume H suggest that with no additional source mass, approximately 10 years will be required for the perimeter recovery system to fully intercept Plume H (Exhibit G.17)

7.1.6 Plume H: Natural Attenuation

With no additional source mass Plume H would drop below 5 µg/L within 10 to 15 years. Simulations suggest that the plume would be intercepted by the D4/D5 recovery system in Zone 1 as the concentrations diminished to below 5 µg/L (Exhibit G.17).

7.2 Plume B

7.2.1 PCE Contaminant Distribution

For the purpose of model simulation, the source mass concentration for Plume B was located in the cell containing the highest field measured concentration of PCE (2,700 µg/L). Since the simulated source mass is constant, rather than declining and may be narrower than the cell width, the concentration was set at 1,000 µg/L in one model cell. The simulated source mass is equivalent to approximately 1.14 lbs (0.08 gal)/year. At this source concentration, approximately 10 years is required to simulate the mapped concentration distribution (Exhibit G.3).

7.2.2 Plume B: Steady State Simulation of PCE

Under the conditions of no further action and a constant source, model simulations show that after 50 years the contaminant distribution area exceeding 100 µg/L would approximately double in size (Exhibit G.18). The complete lateral extent of the PCE distribution cannot be evaluated because of the limited model domain in the northeast off base area. In addition, because the source area and mass has not been identified, it is not

known whether there is sufficient PCE in the unsaturated zone soils to serve as a continuous source.

7.3 Plumes D and F

Plume(s) D is defined by four separate small plumes, two comprised of TCE and two of PCE. Plume F contains very low concentrations of PCE.

7.3.1 Plume D: TCE Contaminant Distribution

The simulated source mass for the Plume D TCE concentration was set at 100 μg/L in the cell containing the highest measured hit of TCE (240 μg/L) in the plume. Simulations with the 100 μg/L continuous source suggest that the distribution is approximately 5 years old (Exhibit G.19). The simulated source mass is equivalent to 0.05 lbs. (0.004 gal)/year. Simulated groundwater flow in the model is to the southeast, while the actual mapped TCE distribution is almost due east of the source. This discrepancy probably results from small scale preferential flow paths within the aquifer that are not accounted for with the groundwater flow model. The general size and concentration distribution of the simulated plume are similar to the mapped plume.

7.3.2 Plumes D and F: PCE Contaminant Distribution

A simulated source mass for the Plume D PCE concentration was set at a 75 μg/L continuous source located in the cell with a measured concentration (150 μg/L) of PCE in the area. With a continuous source of 75 μg/L, the time required to simulate the mapped Plume D PCE distribution is approximately 5 years (Exhibit G.20). The simulated source mass is equivalent to 0.02 lbs. (0.001 gal)/year. A source mass for PCE was not simulated for the PCE plume defined by well ST007MW053 because detections of PCE in this well fluctuate greatly from year to year and PCE is not detected in the immediate surrounding wells, up or downgradient. As a result, it was not considered possible to accurately simulate the fate and transport of PCE based solely on this well. However, recovery system simulation of Plume D does include this area.

7.3.3 Plume D: Steady State Simulation of TCE

With a continuous source of 100 μg/L, simulations suggest that more than 30 years would be required for Plume D TCE to reach steady-state (Exhibit G.21).

7.3.4 Plume D: Steady State Simulation of PCE

With a continuous source of 75 μg/L, simulations suggest that it would require approximately 40 years for Plume D to reach a steady-state concentration distribution (Exhibit G.22).

7.3.5 Plume D: Source Control and Natural Attenuation

Source control for Plume D was simulated using a total of four recovery wells. Two recovery wells (5 gpm total) were located inside the 100 μg/L contour for TCE, one recovery well (7 gpm) was located within the 100 μg/L contour for PCE, and one recovery well (5 gpm) located near ST007MW053. The total recovery rate for the Plume D system is 17 gpm. (Exhibit G.23).

Source control for the northernmost portion of plume D (TCE) was not simulated because the maximum concentration in this area is 16 μg/L.

With source control, fate and transport simulations suggest that the current Plume D TCE distribution would decrease to concentrations less than 5 μg/L in approximately 15 to 20 years (Exhibit G.24).

With source control, fate and transport simulations for Plume D PCE indicate that the remaining PCE distribution would decrease to less than 5 μg/L in approximately 30 years (Exhibit G.25).

7.3.6 Plume F: Natural Attenuation

Assuming no continuous source exists, simulations of the low concentrations of PCE in Plume F would require 15 to 20 years to reach concentrations less than 5 μg/L (Exhibit G.26).

Simulation suggests that Plume D and the western portion of Plume F may be intercepted by the CS-2 recovery systems. However, by the time these plumes reach CS-2 (at the base boundary), the concentrations would be well below 5 μg/L.

7.3.7 Plume D: Downgradient Perimeter Control

Downgradient perimeter control for the composite of plume D was simulated using 16 recovery wells approximately 100 to 300 ft apart. Recovery wells produced between 0.5 and 2.5 gpm each. Full capture was simulated with approximately 35 gpm total recovery (Exhibit G.27).

Fate and transport simulations of Plume D suggest that 5 to 10 years would be required to recover the plumes with down gradient recovery systems (Exhibit G.28).

The actual recovery rates, number of recovery wells, and well spacing required for full perimeter control of Plume D may vary from those simulated in the model.

7.4 Plume I

7.4.1 PCE/TCE/DCE Contaminant Distributions

MT3D simulations were only run for the PCE distribution of Plume I. TCE and DCE concentrations in the same area have a lesser lateral extent and lower concentrations than the PCE in the same area. The latter plumes also have lower Kd values and, as a result, migrate and attenuate more rapidly than PCE. As a result, PCE will be the slowest of the existing contaminants to be remediated. Simulation of PCE is, therefore, considered to be representative of the time required to achieve remediation through various alternatives.

Three source mass concentrations were used to simulate the Plume I PCE distribution. A 1,000 μg/L continuous source was located in Zone 5 in the cell with the highest measured concentration of PCE (1,300 μg/L). Two additional continuous sources of 150 μg/L each were located at a high concentration area in Zone 3, just southeast of Building 375. Using these three source masses, 30 years was required to simulate the Plume I mapped PCE concentration (Exhibit G.29). The total simulated source mass is equivalent to 6.7 lbs. (0.49 gal)/year.

7.4.2 Plume I: Source Control and Natural Attenuation

Source control for Plume I was simulated using a recovery trench. A recovery trench was simulated based on the depth to Navarro, steep groundwater gradient and minimal infrastructure conflicts. The simulated recovery trench is 750 ft long with a control head set 4 ft below the static potentiometric surface. Full capture was simulated with approximately 20 gpm recovery rate (Exhibit G.30).

Fate and transport simulations indicate that approximately 10 years would be required to recover the central high concentration area of Plume I.

With source control, fate and transport simulations indicate that the Plume I PCE distribution in Zone 5 would be intercepted by the CS-2 recovery systems at concentrations above 5 μg/L. Approximately 20 years was required to simulate capture of the PCE plume by the CS-2 recovery system (Exhibit G.31). Some portions of Plume I bypass to the southeast of the CS-2 recovery systems.

7.4.3 Plume I: Downgradient Perimeter Control and Upgradient Injection

For Plume I, upgradient injection wells were simulated in conjunction with the downgradient recovery trench in order to assess the potential effects on groundwater travel time and remediation efficiency.

Five upgradient injection wells at 2 gpm each (10 gpm total) were simulated. The head in the downgradient recovery trench was set five ft below the static potentiometric surface. Trench recovery was 26 gpm. Particle tracking was then used to compare simulated ground water velocities between the system operating with only the recovery trench (Section 7.4.2 of this appendix) and the system operating injection wells in conjunction with the recovery trench. Particle locations were plotted on flow lines at 1-year intervals.

Exhibits G.32 and G.33 show the results of the particle tracking. Groundwater travel time from the trailing edge of the Plume I hot spot to the recovery trench without injection wells is approximately 3 to 4 years (Exhibit G.32). Groundwater travel time from the trailing edge of Plume I to the recovery trench with injection wells is 2 to 4 years (Exhibit G.33).

Even though the head differential between the injection wells and the recovery trench was increased by 4 ft, is does not create a significant change in gradient over the 1,200 ft plume length. In general, the saturated thickness of the aquifer as compared to the plume size is not great enough to allow large changes in gradients to be induced.

Groundwater velocity and volume are the principal factors affected by the additional injection well flux Although an increase in groundwater velocity can increase plume movement, there is not a linear relationship between the two because factors such as diffusion, dispersion, and sorbtion serve to slow contaminant migration. This is evidenced by comparing the groundwater travel time from the flow model to the plume travel time calculated by the fate and transport model.

Because the injection wells increase the groundwater volume within the system, recovery rates must be increased to maintain or increase the groundwater gradient. This increases the total treatment volume for the entire system. Although injection of treated water may

decrease contaminant concentrations, it will not change the total contaminant mass to be recovered by the treatment system.

Although smaller plumes are more likely to respond to increased groundwater gradients, their remediation time is generally too short to justify the additional capital expenditure.

7.4.4 Plume I: Base Boundary Perimeter Control

See Section 7.5 on Zone 2 Perimeter Control below.

7.5 Plume J

7.5.1 PCE Contaminant Distribution

The maximum PCE concentration in Plume J is 120 μg/L at the west side of the plume. However, simulated flow directions within the model suggest that the actual source mass should be north of the existing high concentration location. Therefore, for the purpose of the MT3D simulations, the simulated source mass for this plume was set at 100 μg/L and located in the northeast section of the plume. Given this 100 μg/L continuous source area, approximately 10 years was required to simulate the mapped PCE plume distribution (Exhibit G.34). The total simulated source mass is equivalent to 0.12 lbs. (0.009 gal)/year.

7.5.2 Plume J: Natural Attenuation

Assuming no addition of source mass, fate and transport simulations suggest that the Plume J PCE distribution would drop to below 5 μg/L in approximately 20 years (Exhibit G.35). The residual plume will reach the D-2 recovery system and Leon Creek to the southwest, but the concentrations will be below 5μg/L.

7.5.3 Plume J: Downgradient Perimeter Control

Downgradient perimeter control for Plume J was simulated using recovery wells. Thirteen recovery wells approximately 175 ft apart were simulated along the down gradient edge of the plumes. Recovery rates range from 1 to 5 gpm with a total system recovery rate of 50 gpm. Full capture is simulated at this rate (Exhibit G.36).

Contaminant movement as simulated by the fate and transport model suggests that it would require approximately 5 to 10 years to remediate plume J with a downgradient collection system.

The actual recovery rates, number of recovery wells, and well spacing required for full downgradient perimeter control of Plume J may vary from those simulated in the model.

7.5.4 Plume J: Downgradient Perimeter Control and Upgradient Injection

For Plume J, upgradient injection wells were simulated in conjunction with down gradient recovery wells in order to assess potential effects on the groundwater travel time and remediation efficiency.

Ten upgradient injection wells at 3 gpm each (30 gpm total) and 13 recovery wells at 1 to 5 gpm each (60 gpm total) were simulated. Particle tracking was then used to compare simulated ground water velocities between the system operating with only the recovery

wells (Section 7.5.3 of this appendix) and the system operating injection wells in conjunction with the recovery wells. Particle locations were plotted on flow lines at 1-year intervals.

Exhibits G.37 and G.38 show the results of the particle tracking. Groundwater travel time from the trailing edge of Plume J to the recovery wells without injection wells is approximately 2 years (Exhibit G.37). Groundwater travel time from the trailing edge of Plume J to the recovery wells with injection wells was also approximately 2 years (Exhibit G.38).

7.6 Zone 2 Perimeter Control (Plumes I, D, and F)

The groundwater at the perimeter of Zone 2 along Leon Creek is partially recovered by three existing groundwater recovery systems: the IWTP, CS-2 and CS-2 North Bank, and E-1 systems. However, a substantial gap occurs between the southeast end of the CS-2 systems and the north end of the E-1 recovery trench. Groundwater flow from Plume I and potentially from plumes D and F passes through the gap between these recovery systems and into Leon Creek. An expansion of the Zone 2 recovery systems was simulated to address base perimeter control in this area.

Because of the thin saturated thickness, steep gradient and shallow depth to Navarro a recovery trench was simulated. The simulated trench is 900 ft in length and is located on the north side of Leon Creek, parallel to the base boundary between the CS-2 and E-1 recovery systems. The control head in the trench was set at approximately 2 ft below the static water table elevation. Simulated flow from the recovery trench was 35 gpm with full capture (Exhibit G.39). The actual control head elevation, recovery rate and trench length and location required for full perimeter control may vary from that simulated in the model.

8.0 Remedial Alternative Summary

Table G.3 provides a summary description of each remedial alternative considered for each plume.

9.0 References

CH2M HILL. 1996. *Draft, Volume I, Kelly Air Force Base, IRP Zone 5, Remedial Investigation Report.* April.

CH2M HILL. 1998. *Final, Kelly AFB 1996 Basewide Remedial Assessment, Basewide Groundwater Flow Model Report.* May.

McDonald, M. G. and A. W. Harbaugh. 1988. *A Modular Three-Dimensional Finite Difference Groundwater Flow Model.* U.S. Geological Survey, Techniques of Water-Resources Investigations, Book 6, Chapter A1, 586 pp.

Zeng, C. *MT3D: A Modular Three-Dimensional Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems*. U.S. EPA Kerr Environmental Research Laboratory, Ada, Oklahoma. 1990.

TABLE G.1
Summary of MT3D Packages
Kelly AFB, San Antonio, Texas

Package Name	Description	Required?
Basic Transport Model	Contains definition of the problem, specification of boundary and initial conditions, determination of step size, and preparation of mass balance information	Yes
Flow Model Interface	Reads the file from MODFLOW and prepares the heads and flow terms in form needed by transport model	Yes
Advection	Contains options that control the transport simulation. Solves the concentration change due to advection (process by which solutes are transported along with the movement of groundwater)	No
Dispersion	Solves the concentration change due to dispersion (spread of solutes based on combined effects of mechanical dispersion and diffusion)	No
Sink and Source Mixing	Solves the concentration change due to fluid sink/source mixing. Sink/source terms may include wells, drains, rivers, recharge, and evapotranspiration. The constant-head boundary and general-head dependent boundary are also handled as sink/source terms in the transport model	No
Chemical Reactions	Solves the concentration change due to chemical reactions. The chemical reactions include linear or nonlinear sorption isotherms and first-order irreversible rate reactions (radioactive decay or biodegradation)	No
Utility	Contains number of utility modules that perform general-purpose tasks as input/output of data arrays.	Yes

TABLE G.2
Groundwater Model Characteristics
Kelly AFB, San Antonio, Texas

	Discretization					
Model	**Rows**	**Columns**	**Grid Spacing (ft)**	**Alluvium Thickness (ft)**	**Calibrated Hydraulic Conductivity (ft/d)**	**Navarro Group Elevation (ft NGVD)**
Basewide	99	107	200	0.01-29.2	0.2-600	598.0-675.6
NSA	33	88	40	1.5-29.2	0.2-500	643.2-675.5
ESA	46	75	40	2.7-21.9	0.2-300	633.9-664.7
SSA	45	25	40	2.7-23.5	0.2-600	609.2-658.3
WSA	44	34	40	1.3-18.0	0.2-200	619.8-659.3
Zone 2	42	57	20	5.0-19.2	0.2-271	602.8-623.2

TABLE G.3
Remedial Alternative Summary Table
Kelly AFB, San Antonio, Texas

Plume ID	Remedial Alternative	Remedial System	Description	Flow Rate	Estimated Time for Remediation	Comments
A	Source Control and Natural Attenuation	Recovery Trench	1,000 ft long	17 gpm	Source Area – 5 to 10 yrs; on base plume – 25 yrs	On base plume only
	Perimeter Control at Base Boundary and Natural Attenuation	Recovery Trench or Recovery Wells	3,000 ft trench or 7 recovery wells at 400 ft spacing	50 gpm for either system	Off base plume – 10 yrs	Off base plume is only measured to 1,500 ft from base boundary
	Off Base Recovery	Recovery Wells	12 wells at 400 ft	3 to 5 gpm each for total recovery of 50 gpm	Undetermined	Remediation time depends on actual size of off base plume and use of on base recovery systems
B	No Further Action	None	NA	NA	Steady state cannot be simulated due to model boundaries	Continuous source
D	No Further Action TCE	None	NA	NA	30 years to steady state	No source control
	No Further Action PCE	None	NA	NA	40 years to steady state	No source control
	Source Control and Natural Attenuation	Recovery Wells	4 recovery wells	2.5 to 7 gpm for 17 gpm total recovery	Source control – 5 yrs; remaining plume – 20 to 30 yrs	
	Base Boundary Perimeter Control	See Zone 2 Perimeter Control				
D&G	Downgradient Perimeter Control	Recovery Wells	16 at 100 to 300 ft	1 to 2.5 gpm for 37 gpm total recovery	5 to 10 yrs	Assuming no addition of source mass
F	Natural Attenuation	None	NA	NA	15 to 20 yrs	Assuming no addition of source mass
	Base Boundary Perimeter Control	See Zone 2 Perimeter Control				

Plume ID	Remedial Alternative	Remedial System	Description	Flow Rate	Estimated Time for Remediation	Comments
H	Natural Attenuation	None	NA	NA	10 to 15 yrs	Assuming no addition of source mass; plume intercepted by D4/D5 recovery system
	Downgradient Perimeter Control	Recovery Wells	8 recovery wells 175 ft apart	10 gpm/well = 80 gpm total	10 yrs	Assuming to addition of source mass
I	Source Control and Natural Attenuation	Recovery Trench	750 ft	20 gpm	Source Area – 5 to 10 yrs; remaining plume 20 yrs to CS-2 recovery system	
	Base Boundary Perimeter Control	See Zone 2 Perimeter Control				
	Downgradient Perimeter Control and Upgradient Injection	Recovery Trench and Injection Wells	Recovery trench 750 ft; 5 injection wells at 200 to 400 ft	26 gpm total recovery; 10 gpm total injection	Source area – 5 to 10 yrs	Injection of remediated water only
J	Natural Attenuation	None	NA	NA	15 to 20 yrs	Assuming no addition of source mass
	Downgradient Perimeter Control	Recovery Wells	13 at 175 to 300 ft	1 to 5 gpm for 50 gpm total recovery	5 to 10 yrs	Assuming no addition of source mass
	Downgradient Perimeter Control and Upgradient Injection	Recovery Wells and Injection Wells	13 recovery wells at 175 ft; 10 injection wells at 100 to 200 ft	60 gpm total recovery; 30 gpm total injection	5 to 10 yrs	Assuming no addition of source mass. Injection of remediated water only
Zone 2 Perimeter Control (Plumes I, D, and F)	Base Boundary Perimeter Control	Recovery Trench	900 ft	35 gpm	Undetermined	Dependent on any additional upgradient remediation of plumes

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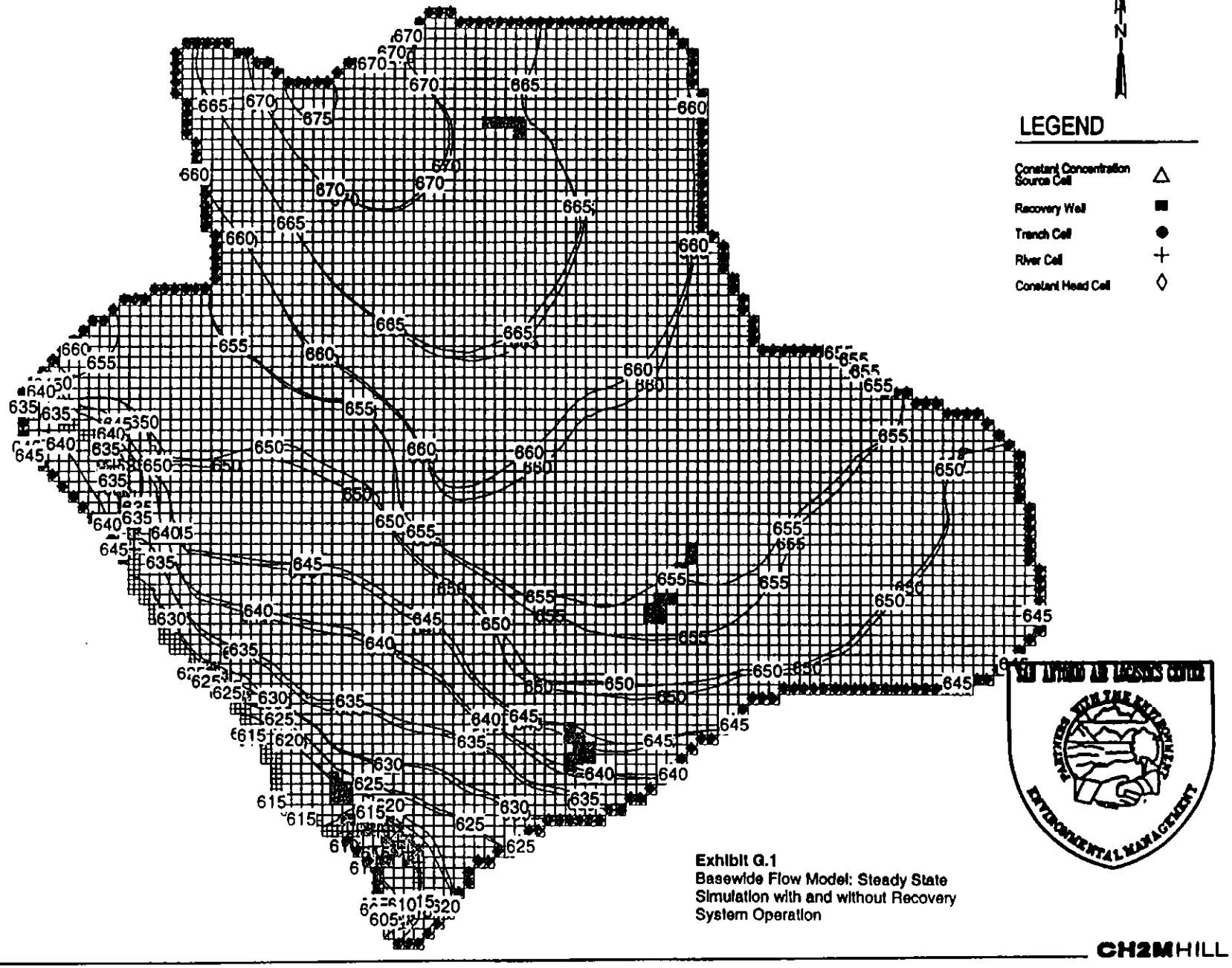

Exhibit G.1
Basewide Flow Model: Steady State Simulation with and without Recovery System Operation

SANCAD\KELLY\DIS_FFS\2DBDRL_LAND.DGN
11-NOV-1996

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CH2MHILL

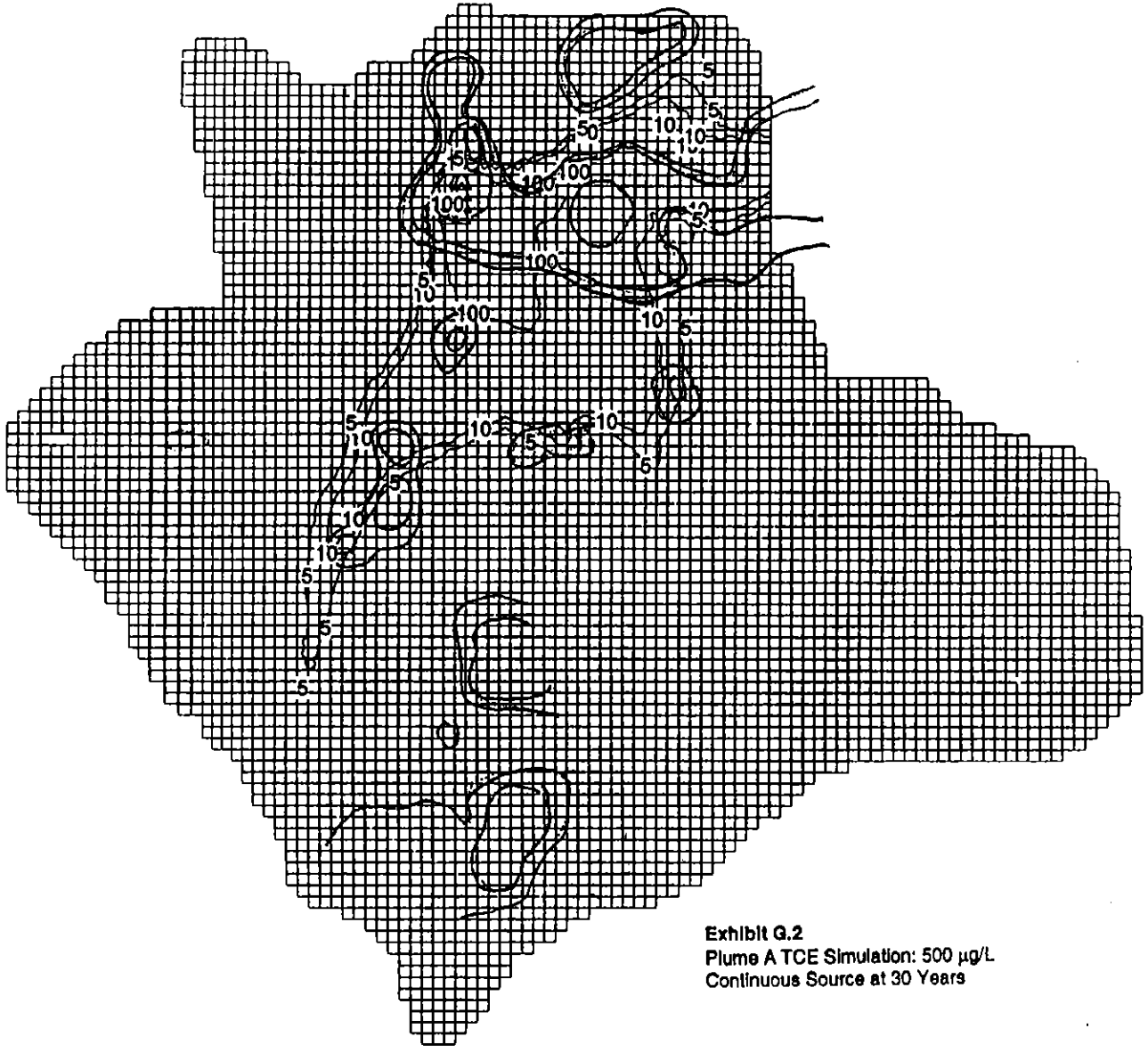

Exhibit G.2
Plume A TCE Simulation: 500 µg/L
Continuous Source at 30 Years

Z

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11-NOV-1

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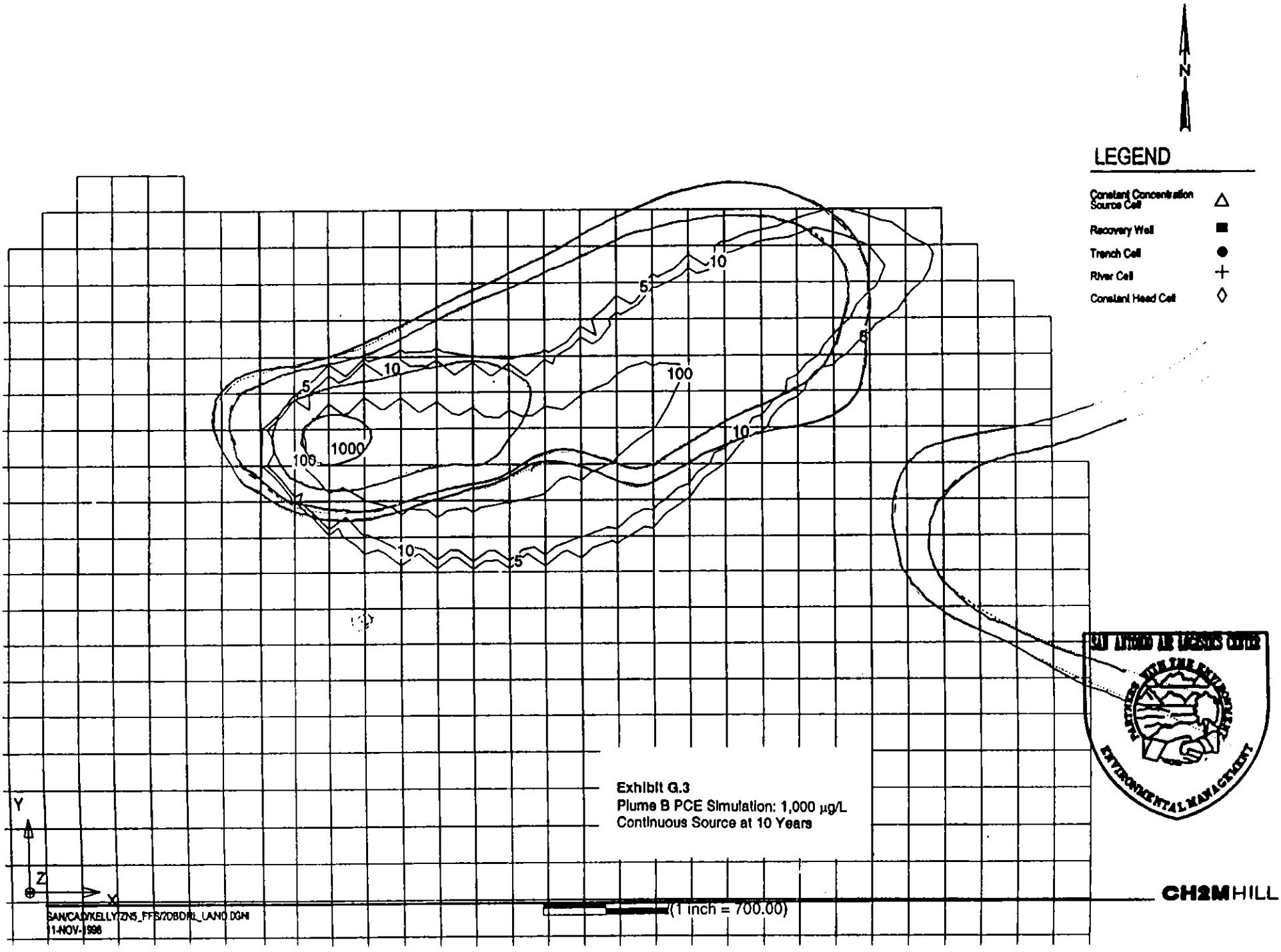

Exhibit G.3
Plume B PCE Simulation: 1,000 µg/L
Continuous Source at 10 Years

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11-NOV-1998

CH2MHILL

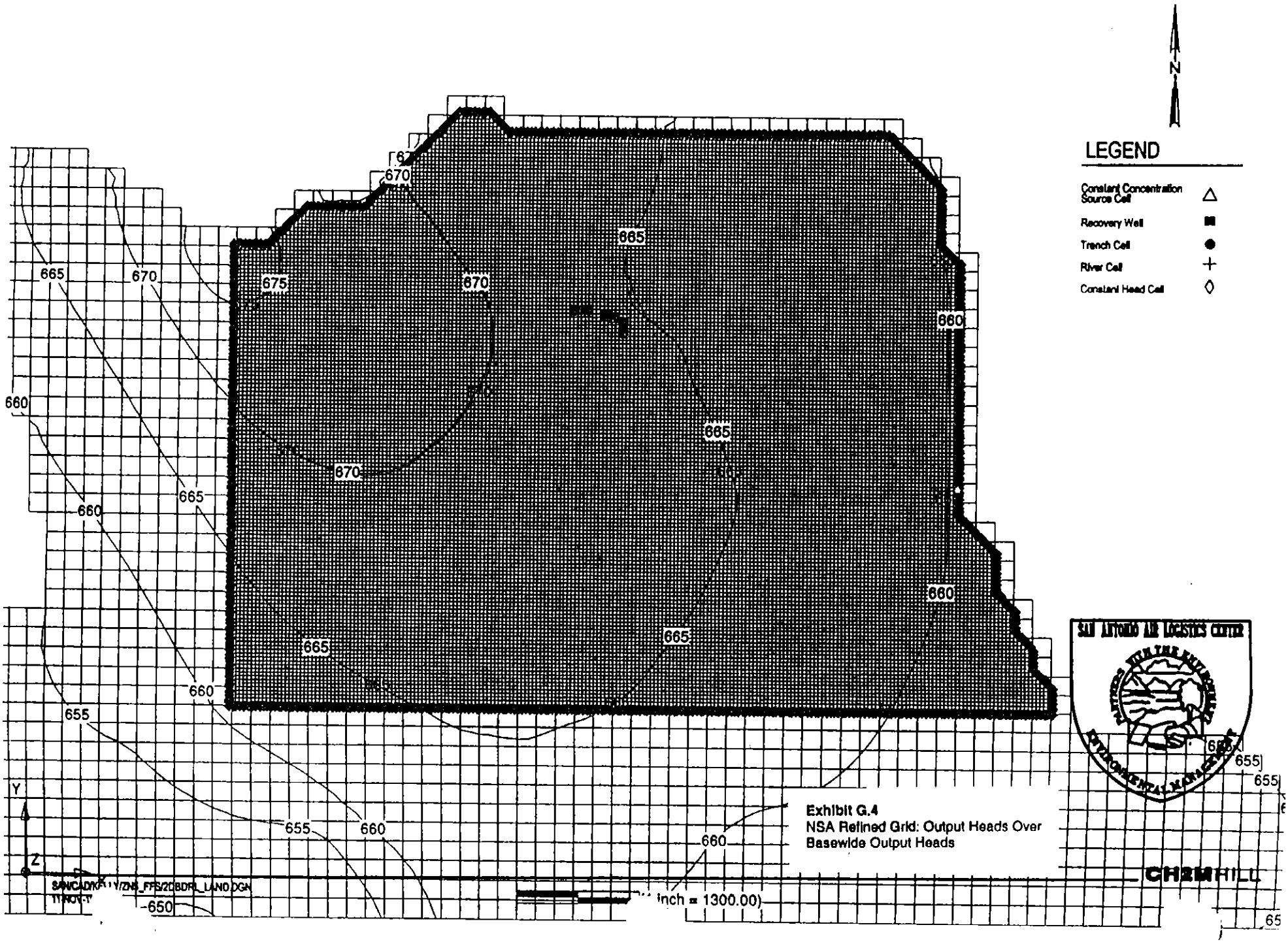


Exhibit G.4
NSA Refined Grid: Output Heads Over
Basewide Output Heads

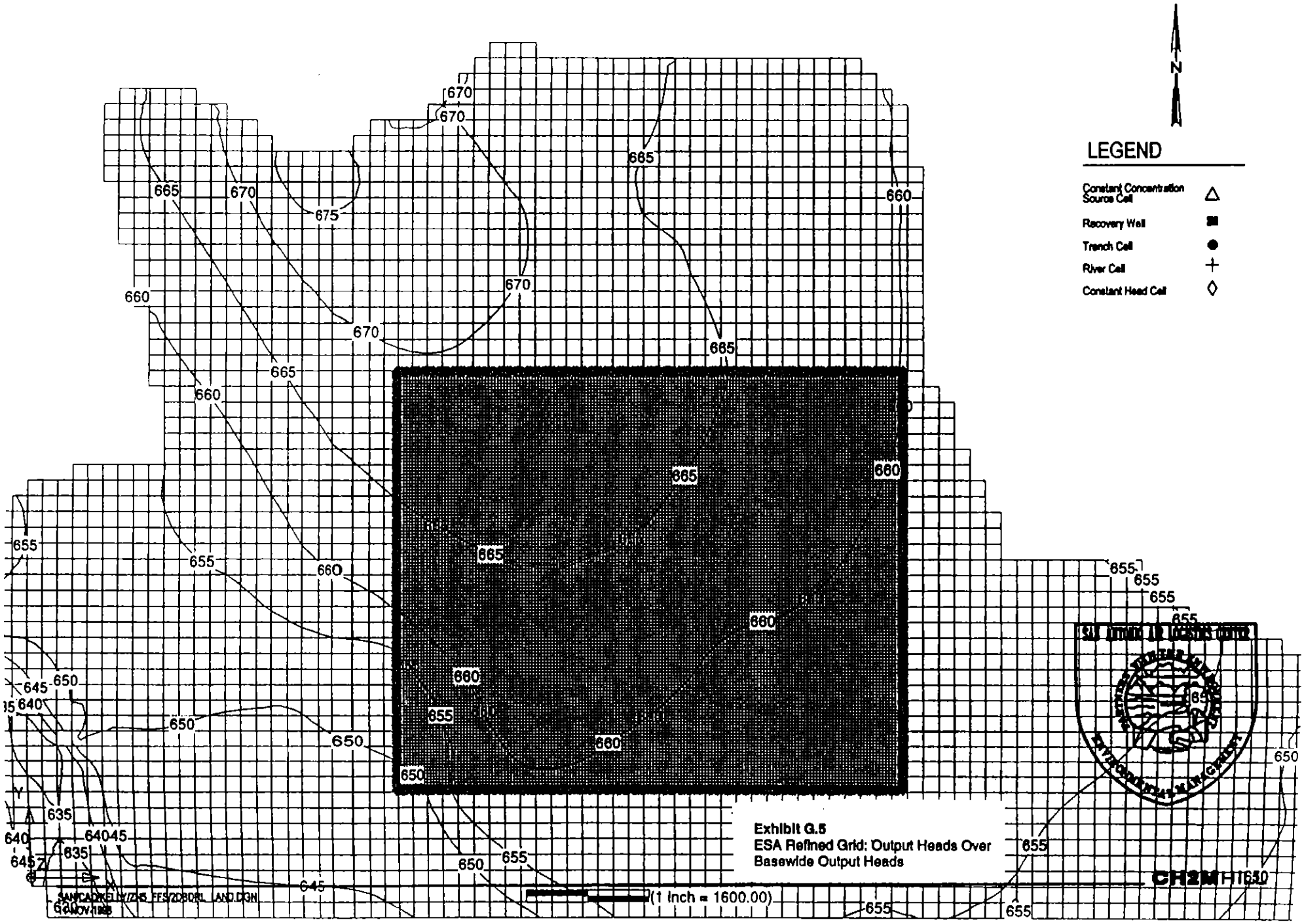


Exhibit G.5
ESA Refined Grid: Output Heads Over Basewide Output Heads

CH2M HILL

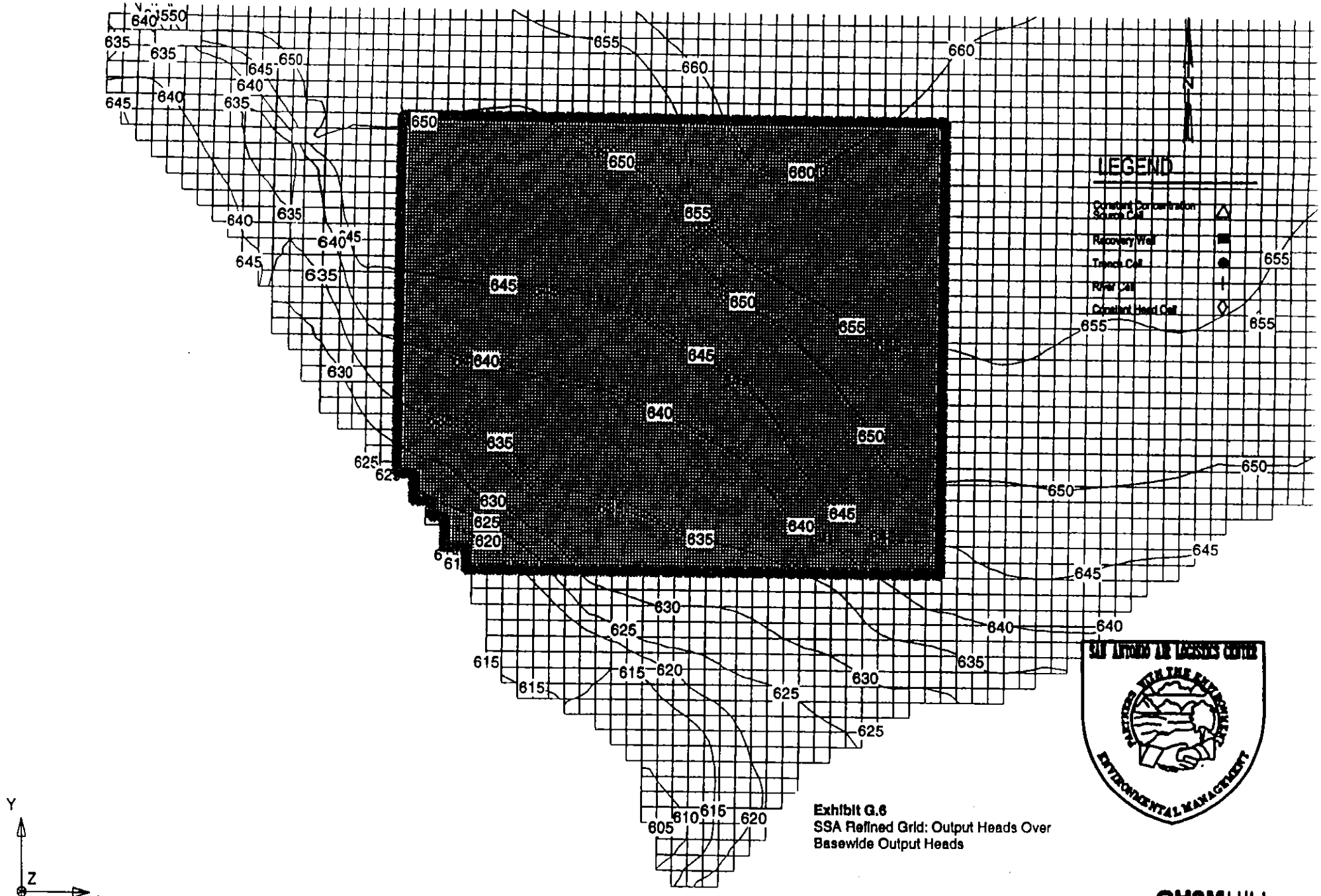


Exhibit G.6
SSA Refined Grid: Output Heads Over Basewide Output Heads

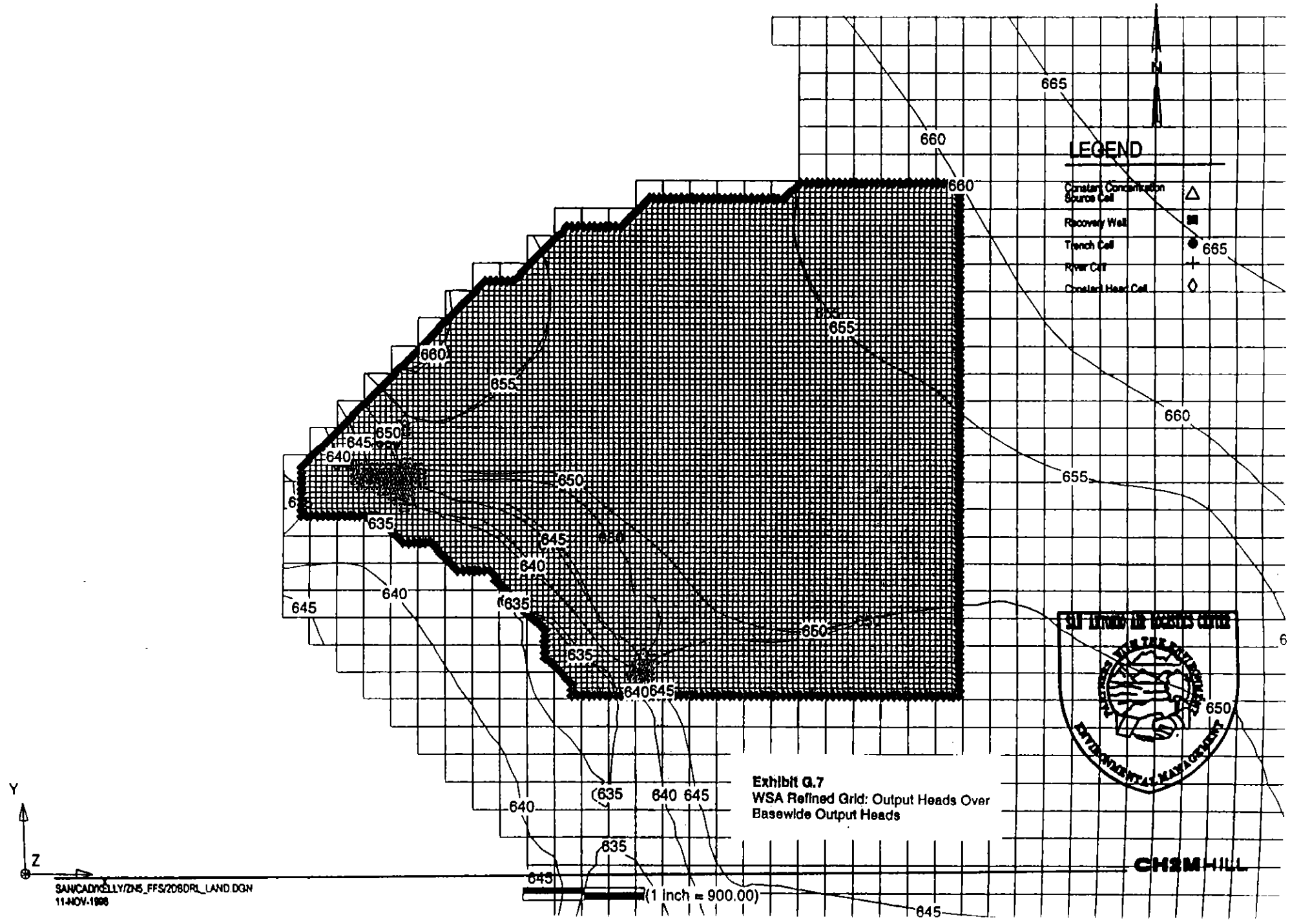


Exhibit G.7
WSA Refined Grid: Output Heads Over Basewide Output Heads

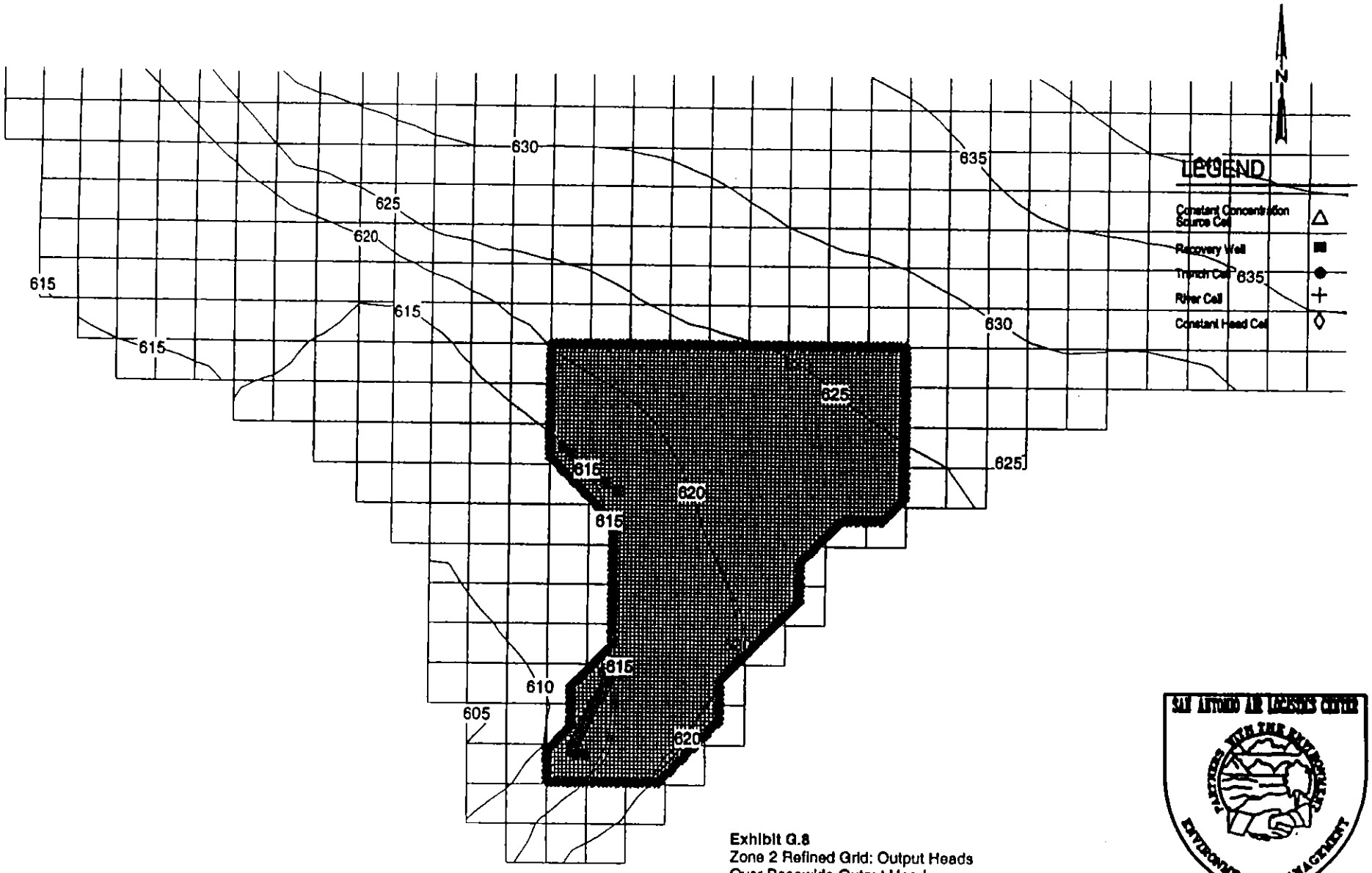
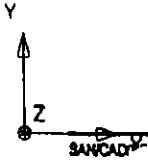


Exhibit G.8
Zone 2 Refined Grid: Output Heads
Over Basewide Output Heads



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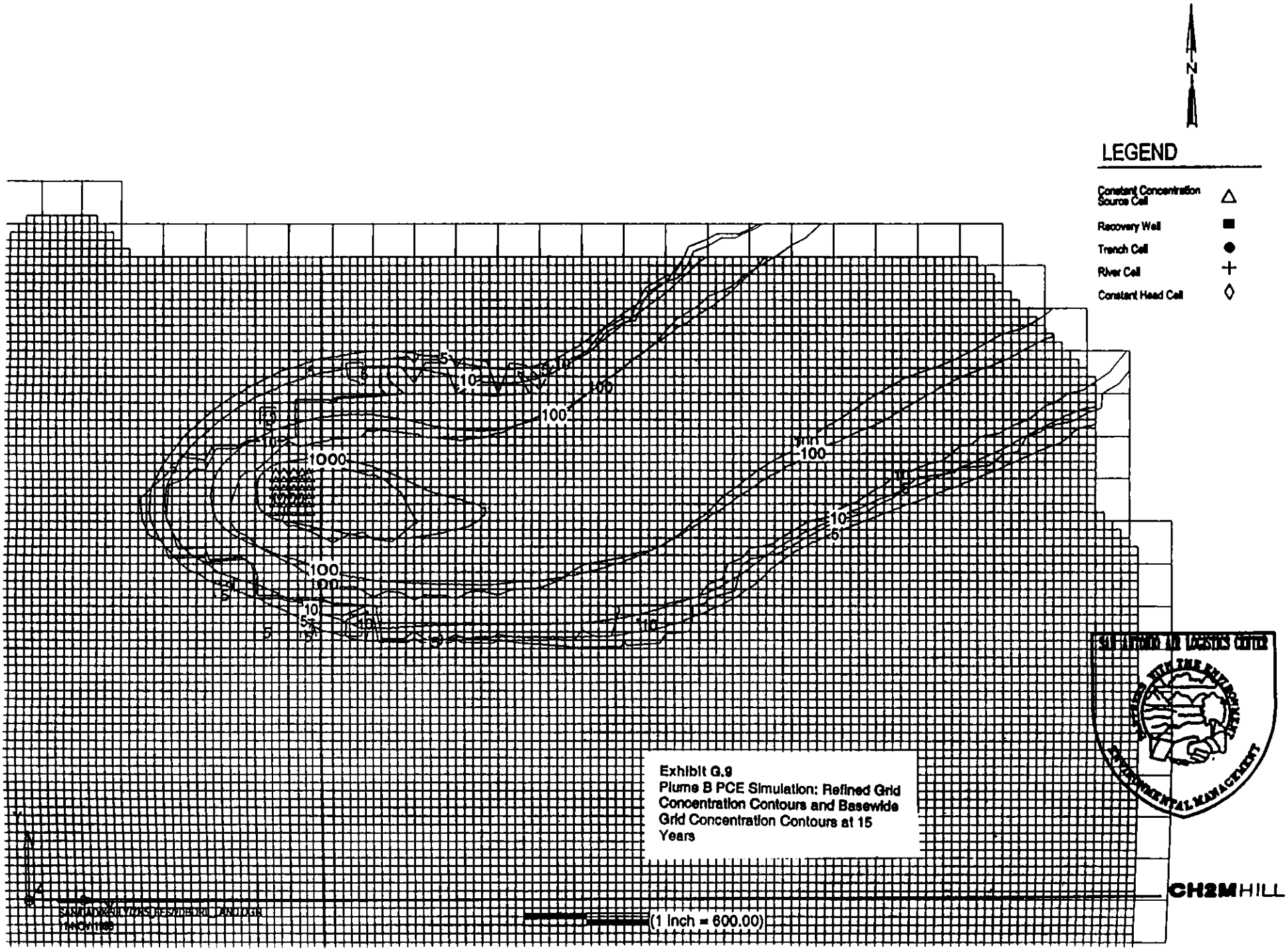


Exhibit G.9
Plume B PCE Simulation: Refined Grid Concentration Contours and Basewide Grid Concentration Contours at 15 Years

CH2MHILL

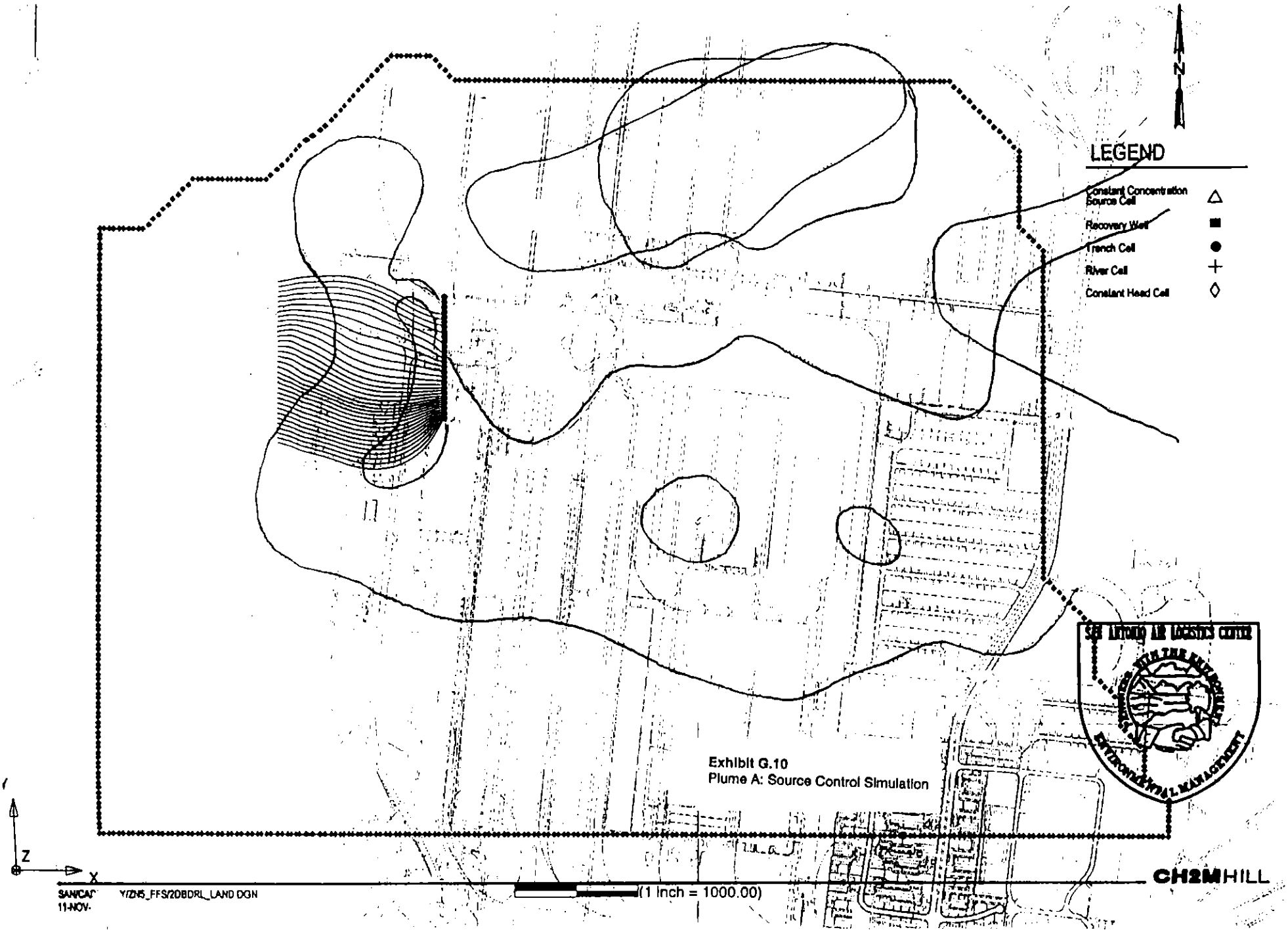
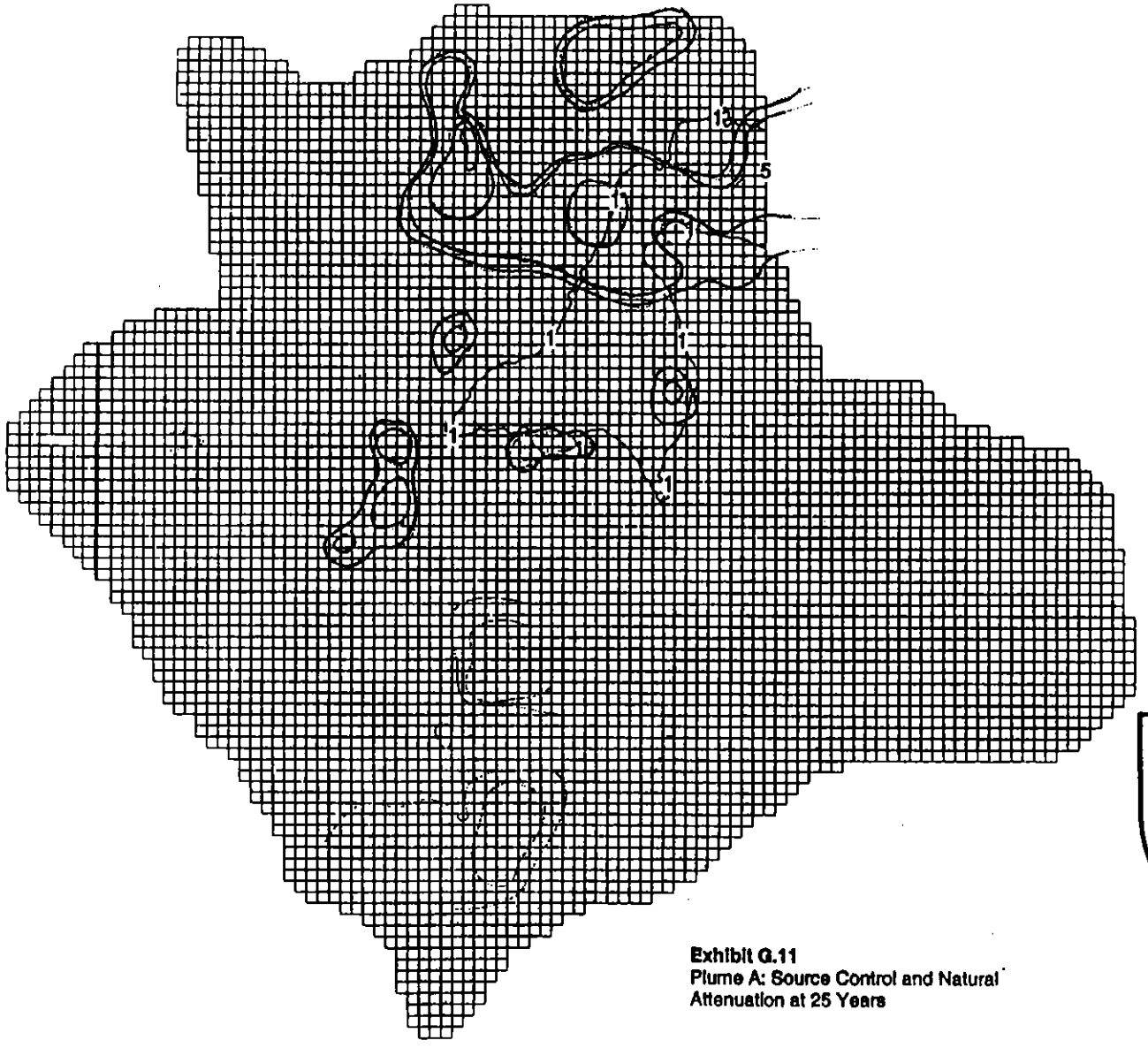


Exhibit G.10
Plume A: Source Control Simulation



N

LEGEND

- Constant Concentration Source Cell △
- Recovery Well ■
- Trench Cell ●
- River Cell +
- Constant Head Cell ◊

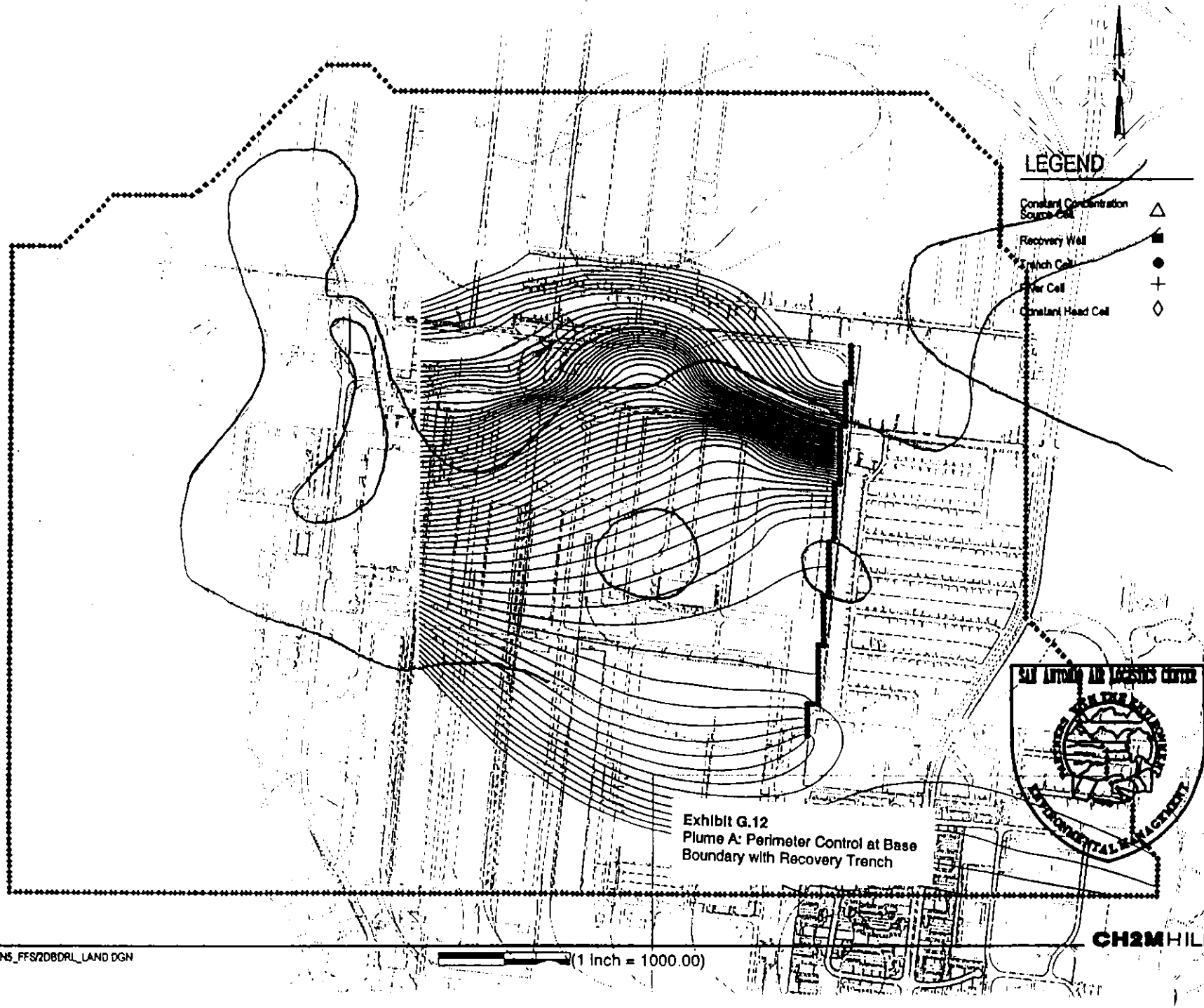
Y
Z
X

Exhibit G.11
Plume A: Source Control and Natural Attenuation at 25 Years

(1 Inch = 3000.00)

SAN/CAD/KELLY/ZN5_FFS/2D80RI_LAND.DGN
11-NOV-1998

CH2MHILL


N
LEGEND
Constant Concentration Source Cell
Recovery Well
Trench Cell
River Cell
Constant Head Cell
Exhibit G.12
Plume A: Perimeter Control at Base Boundary with Recovery Trench
Y
Z
X
SANCAD
11-NOV-
Y:\ZNS_FFS\2DBDRL_LAND.DGN
(1 Inch = 1000.00)
CH2MHILL

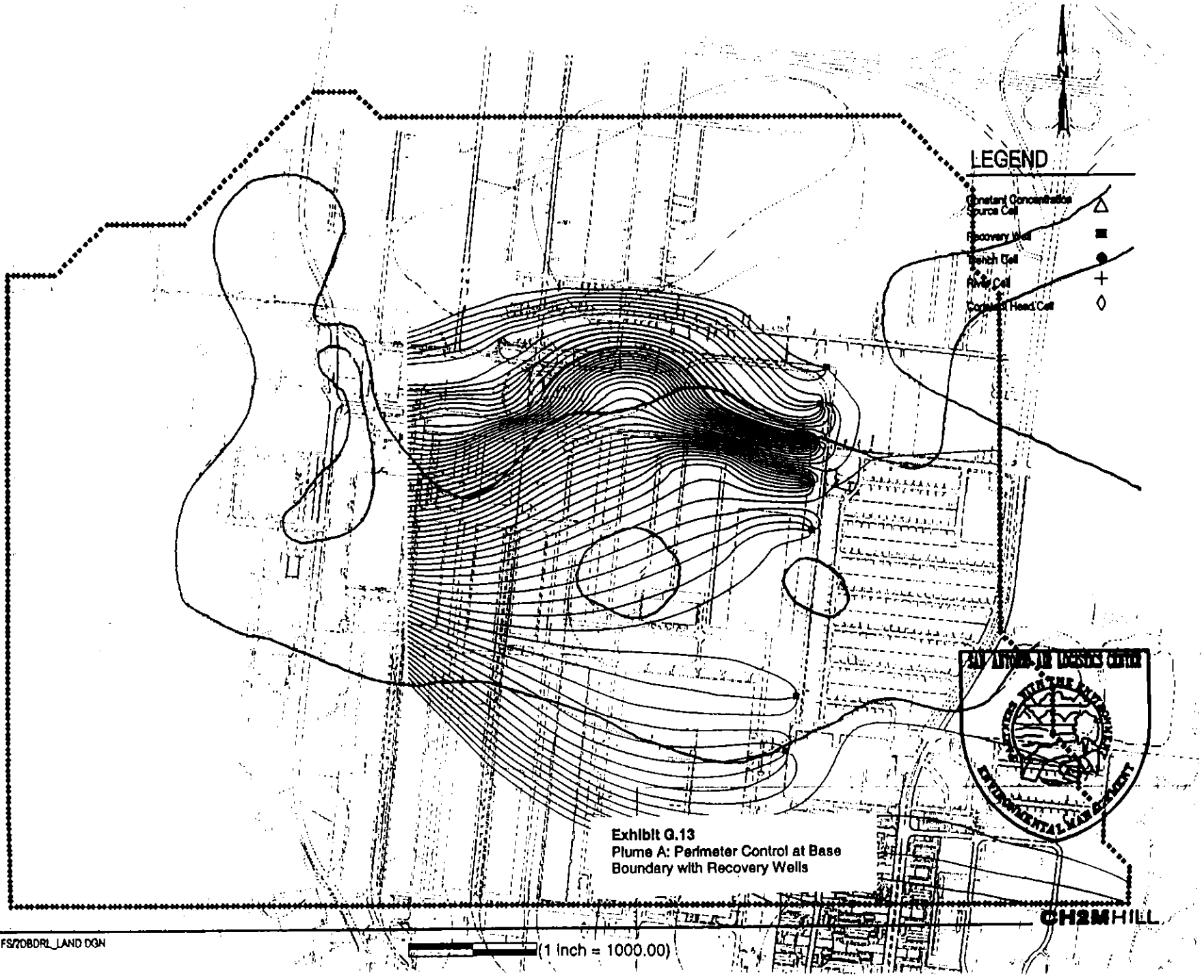
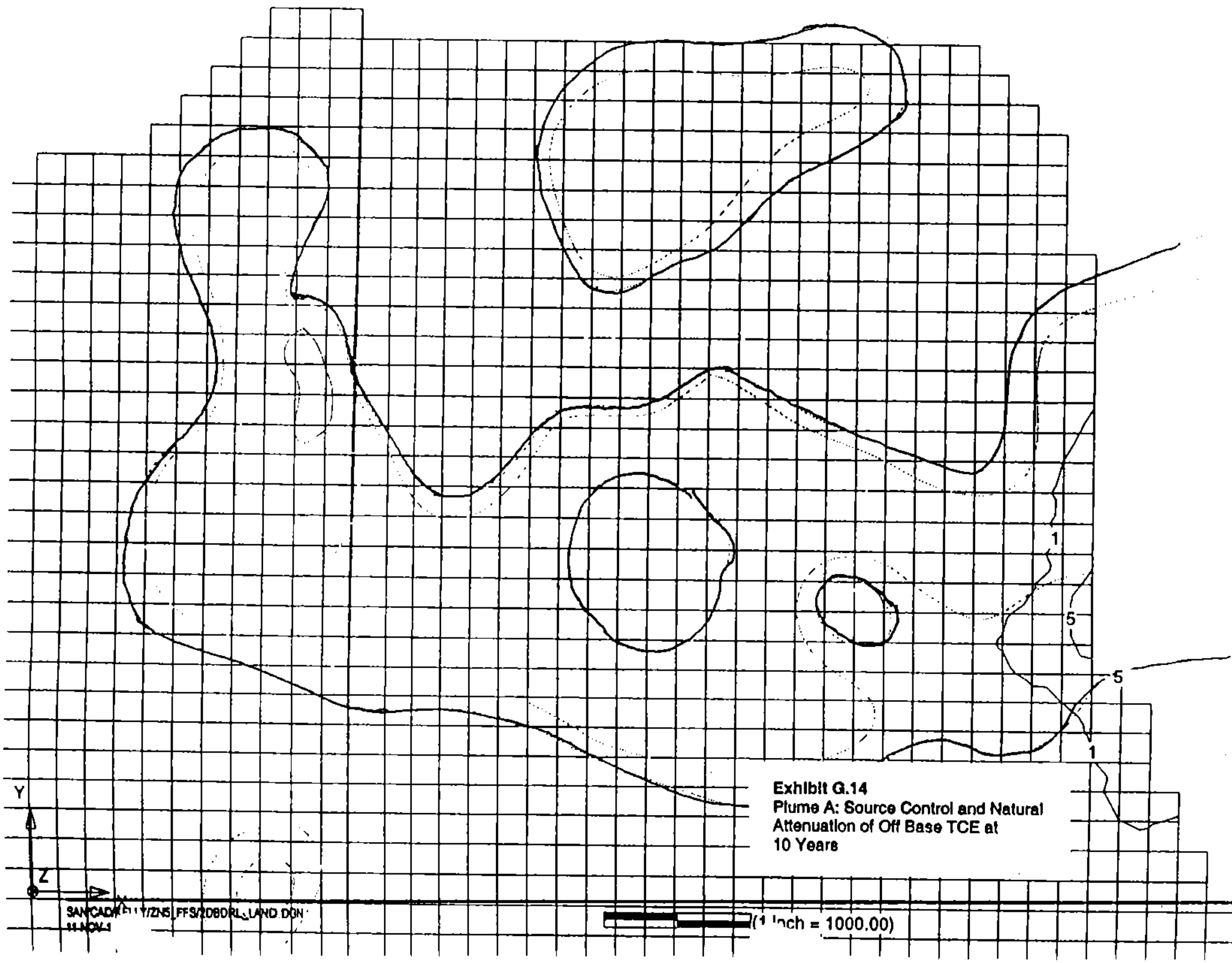


Exhibit G.13
Plume A: Perimeter Control at Base Boundary with Recovery Wells

SAN/CAD/KELLY/ZN5_FFS/20BDRL_LAND.DGN
11-NOV-1998

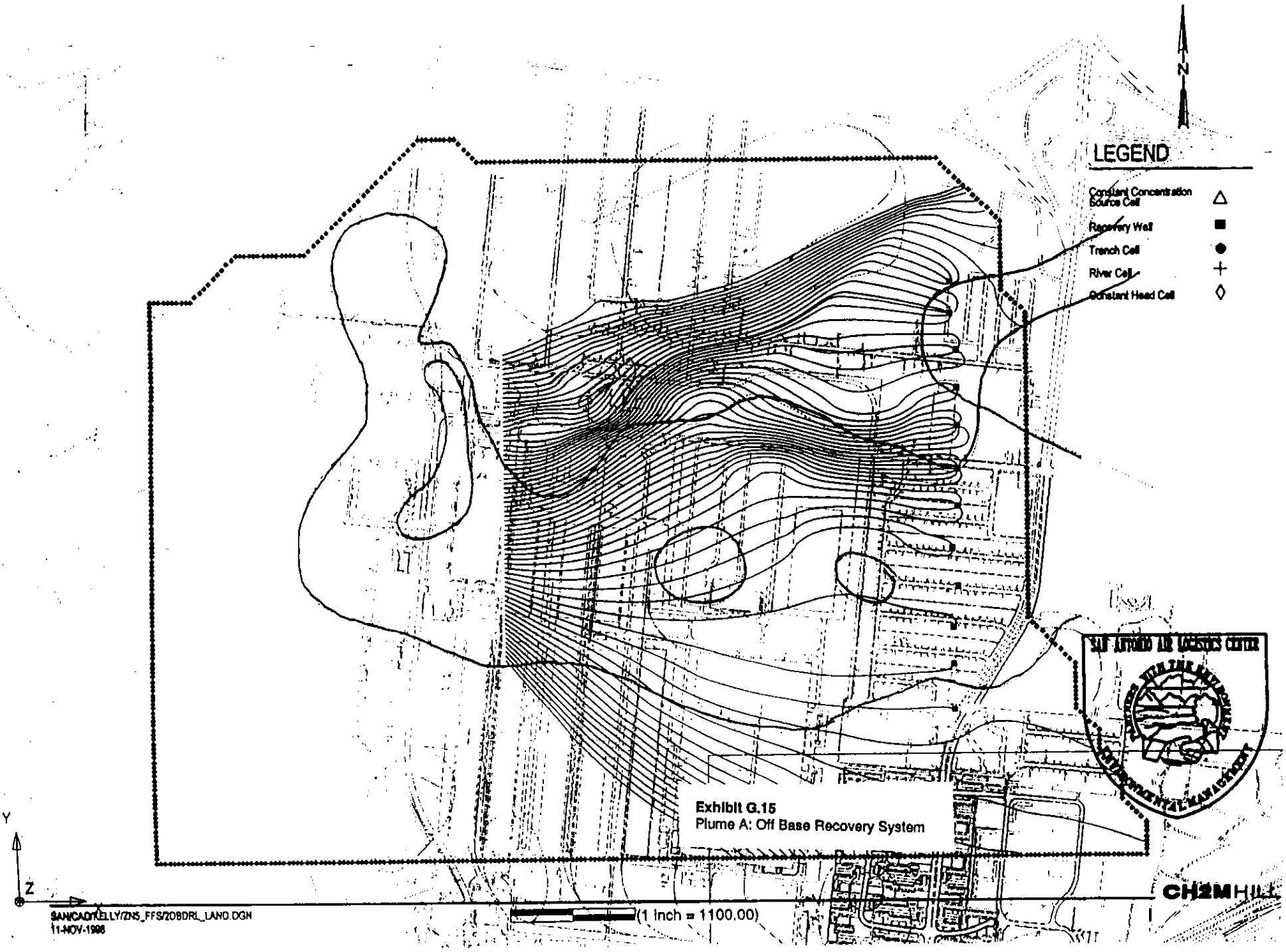


LEGEND

Constant Concentration Source Cell	△
Recovery Well	■
Trench Cell	●
River Cell	+
Constant Head Cell	◊

Exhibit G.14
Plume A: Source Control and Natural Attenuation of Off Base TCE at 10 Years

SAN ANTONIO AIR LOGISTICS CENTER
PARTNERS WITH THE ENVIRONMENT
ENVIRONMENTAL MANAGEMENT


N
LEGEND
Constant Concentration Source Cell
Recovery Well
Trench Cell
River Cell
Constant Head Cell
SAN ANTONIO AIR LOGISTICS CENTER
Exhibit G.15
Plume A: Off Base Recovery System
Y
Z
(1 inch = 1100.00)
CH2MHILL
SAN:CADD\KELLY\ZNS_FFS\208DRL_LAND.DGN
11-NOV-1998

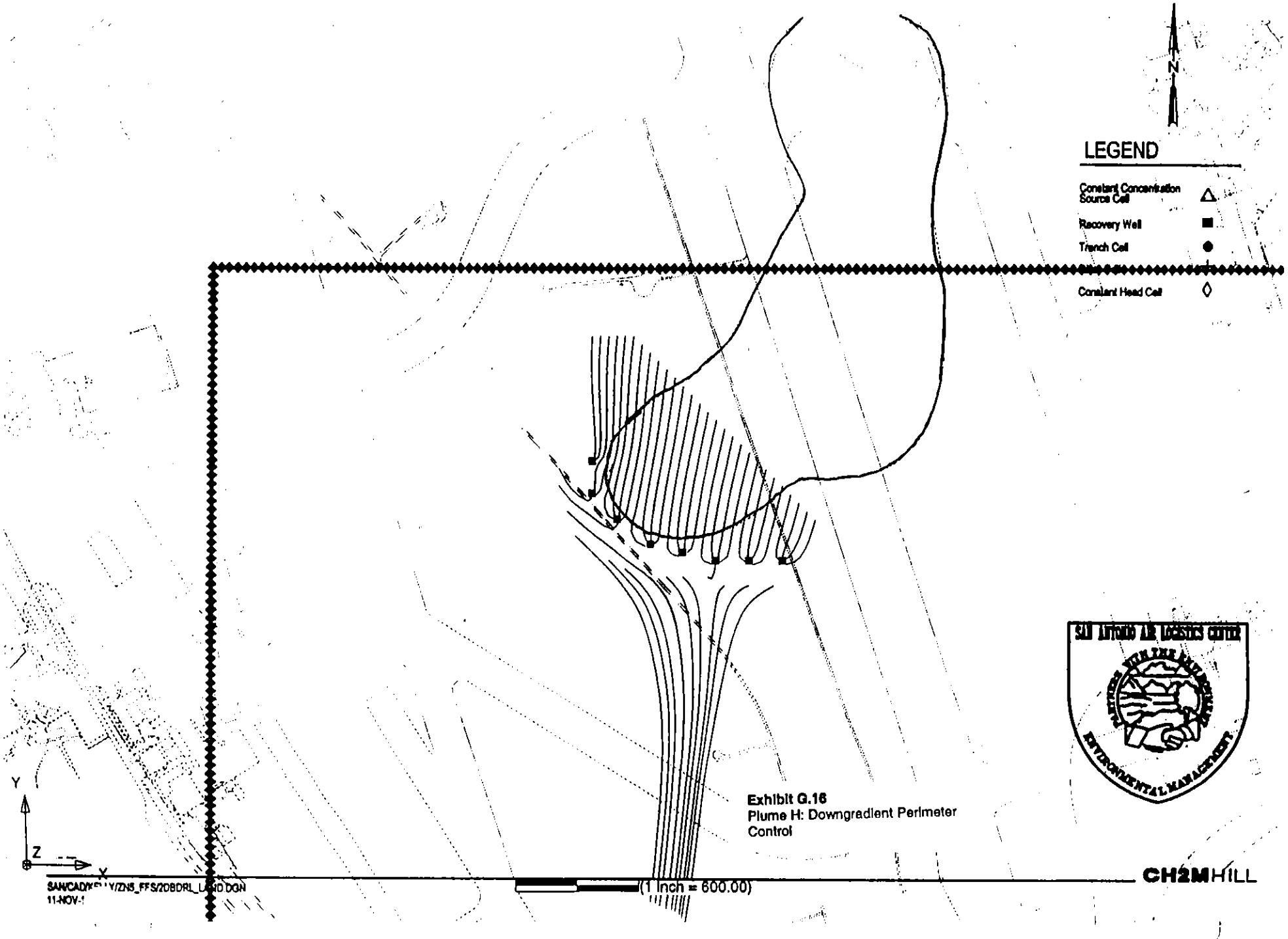


Exhibit G.16
Plume H: Downgradient Perimeter Control

CH2MHILL

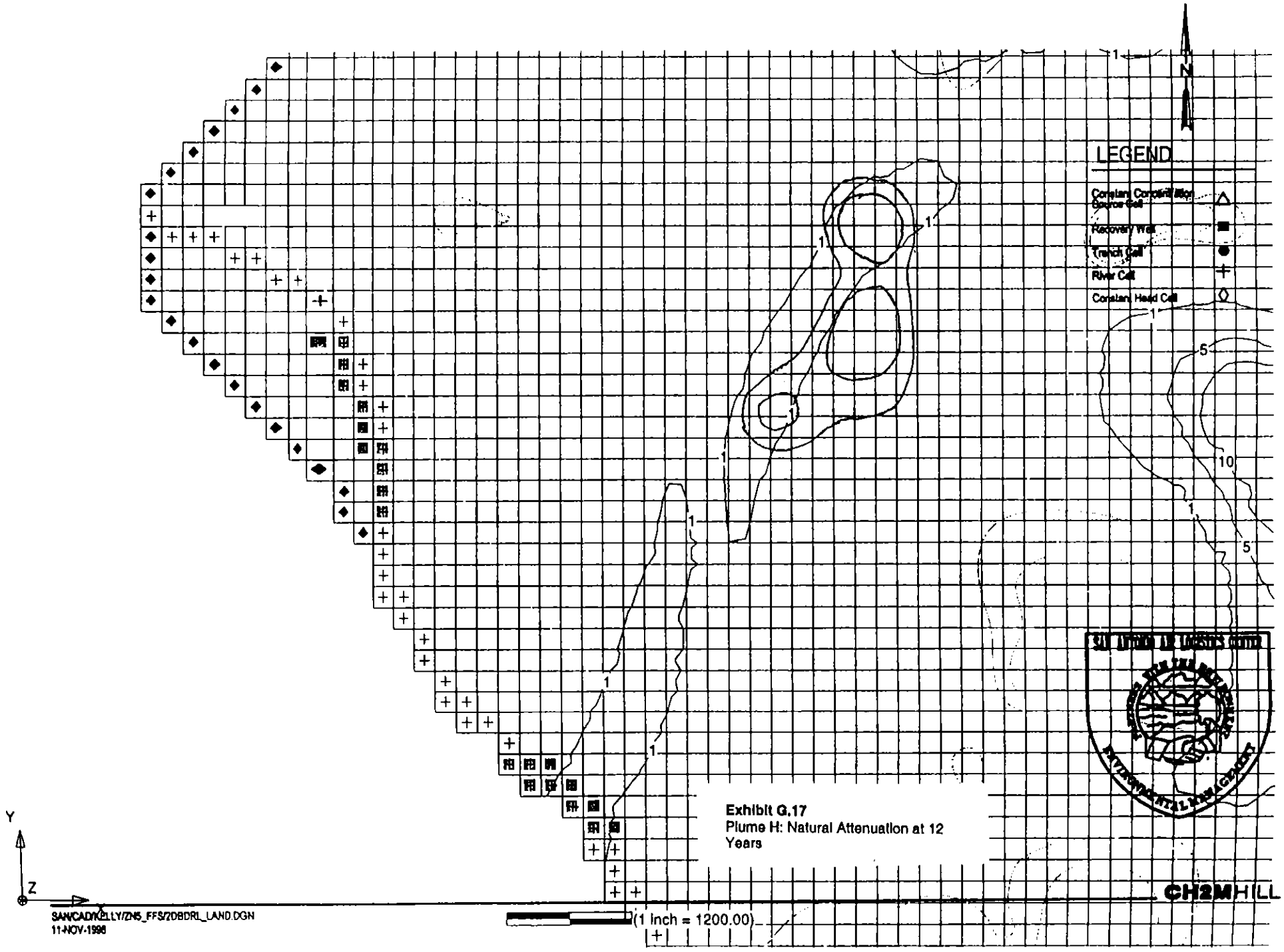


Exhibit G.17
Plume H: Natural Attenuation at 12 Years

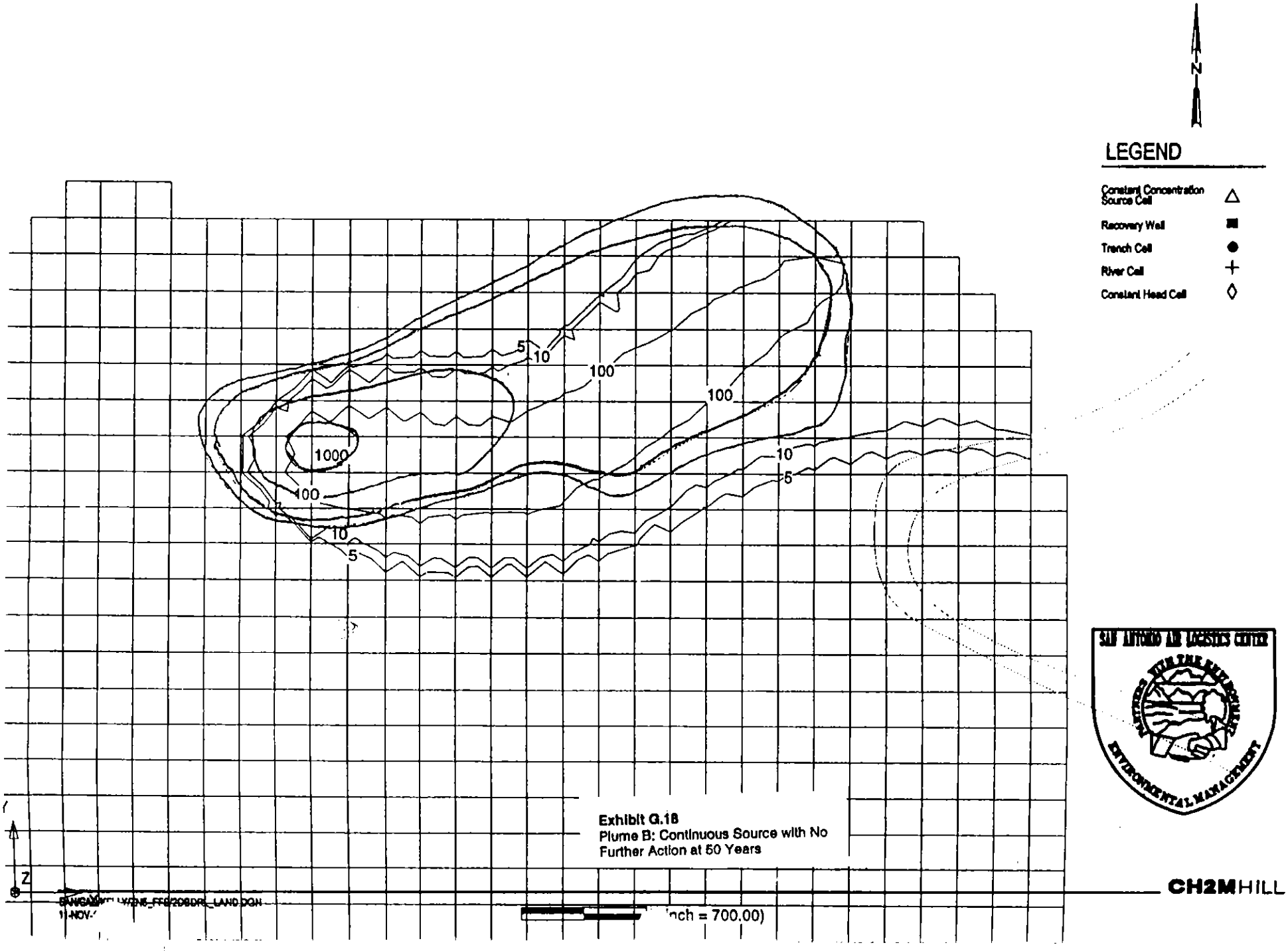


Exhibit G.18
Plume B: Continuous Source with No Further Action at 50 Years

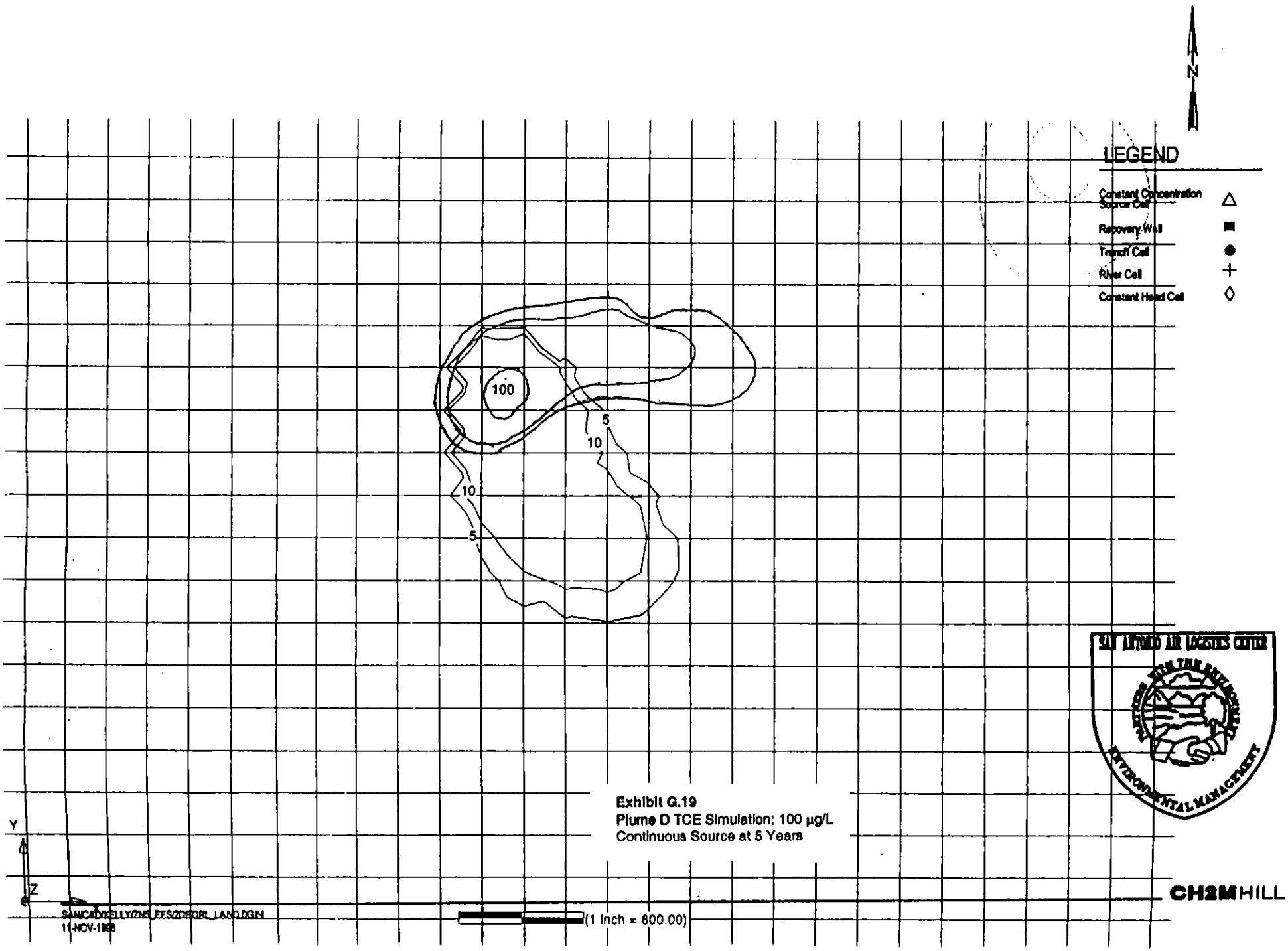


Exhibit G.19
Plume D TCE Simulation: 100 µg/L
Continuous Source at 5 Years

CH2MHILL

SA/ACAD/KELLY/ZNE_FFS/2/EXDR_LAND.DGN
11-NOV-1998

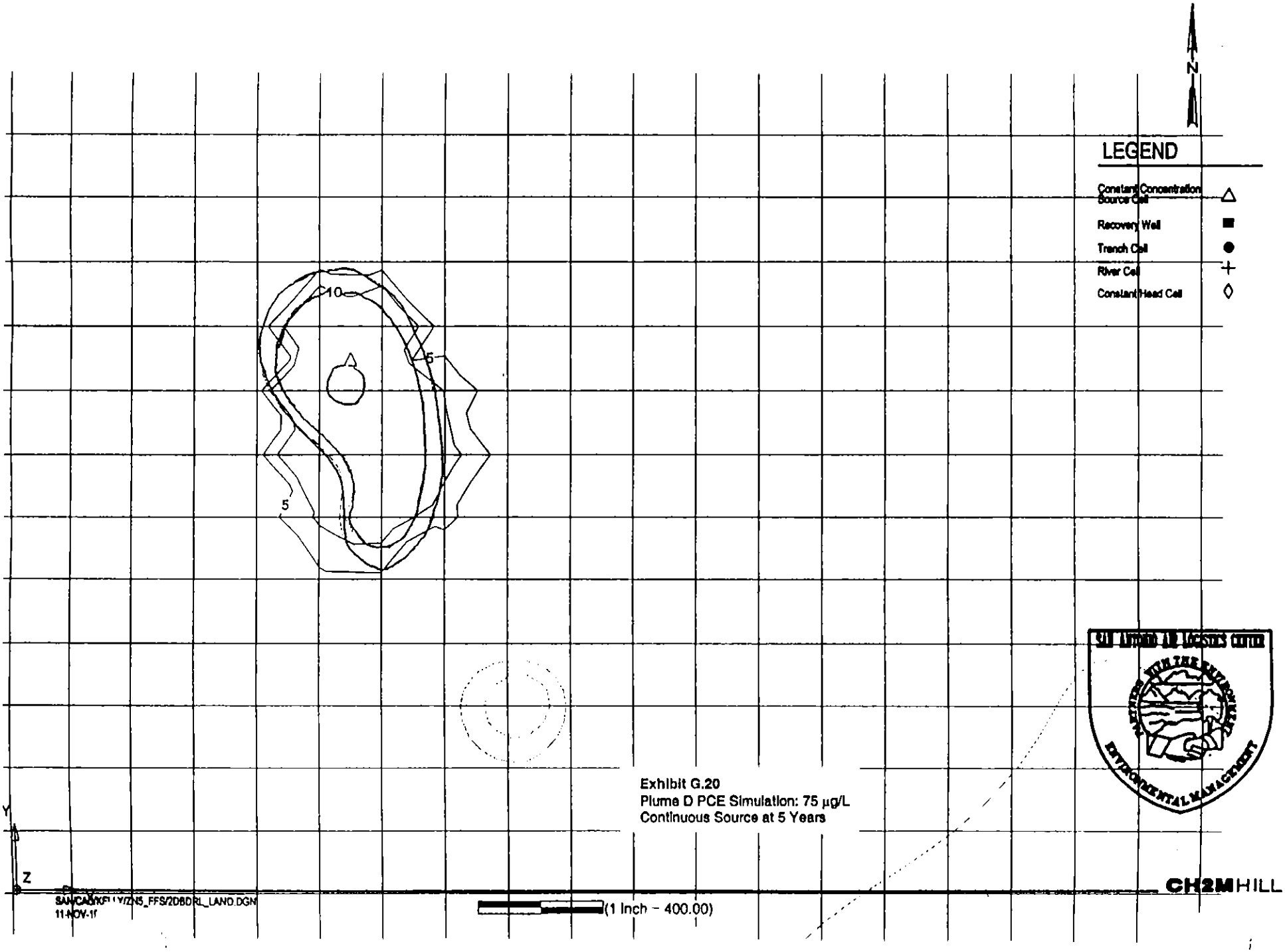


Exhibit G.20
Plume D PCE Simulation: 75 µg/L
Continuous Source at 5 Years

CH2MHILL

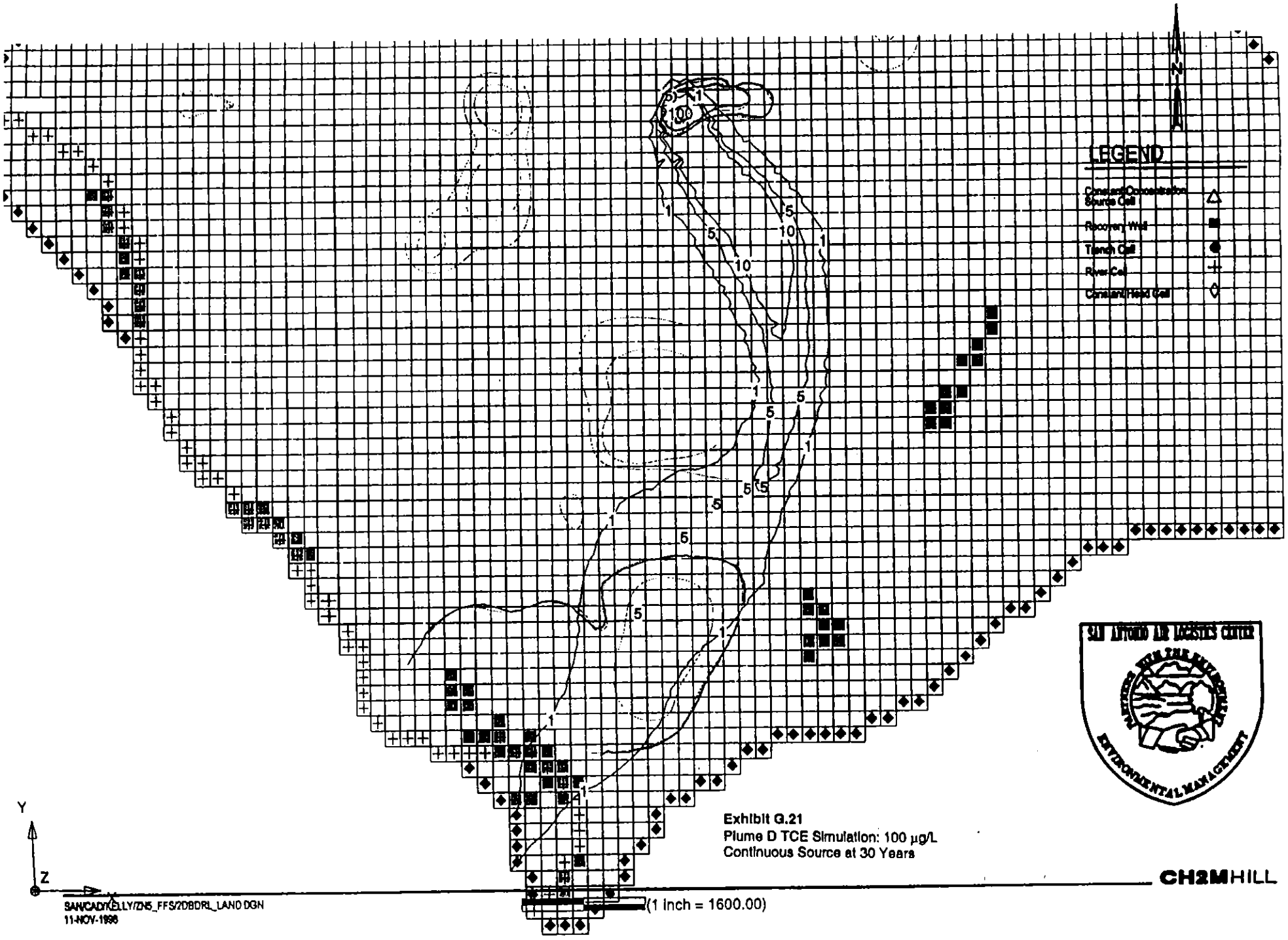


Exhibit G.21
Plume D TCE Simulation: 100 µg/L
Continuous Source at 30 Years

SAN/CAD/KELLY/ZN5_FFS/2DBDRL_LAN0.DGN
11-NOV-1998

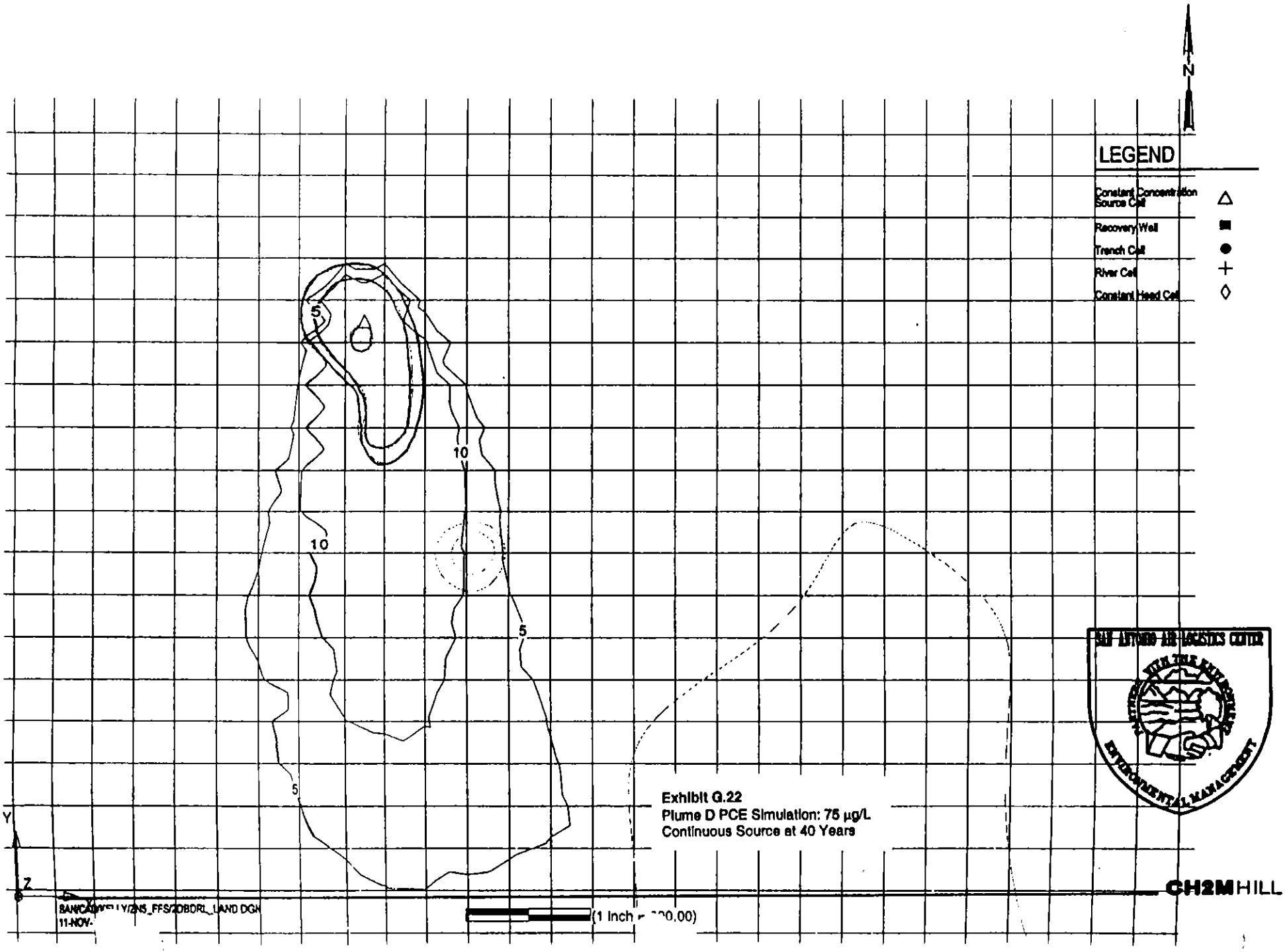


Exhibit G.22
Plume D PCE Simulation: 75 µg/L
Continuous Source at 40 Years

CH2MHILL

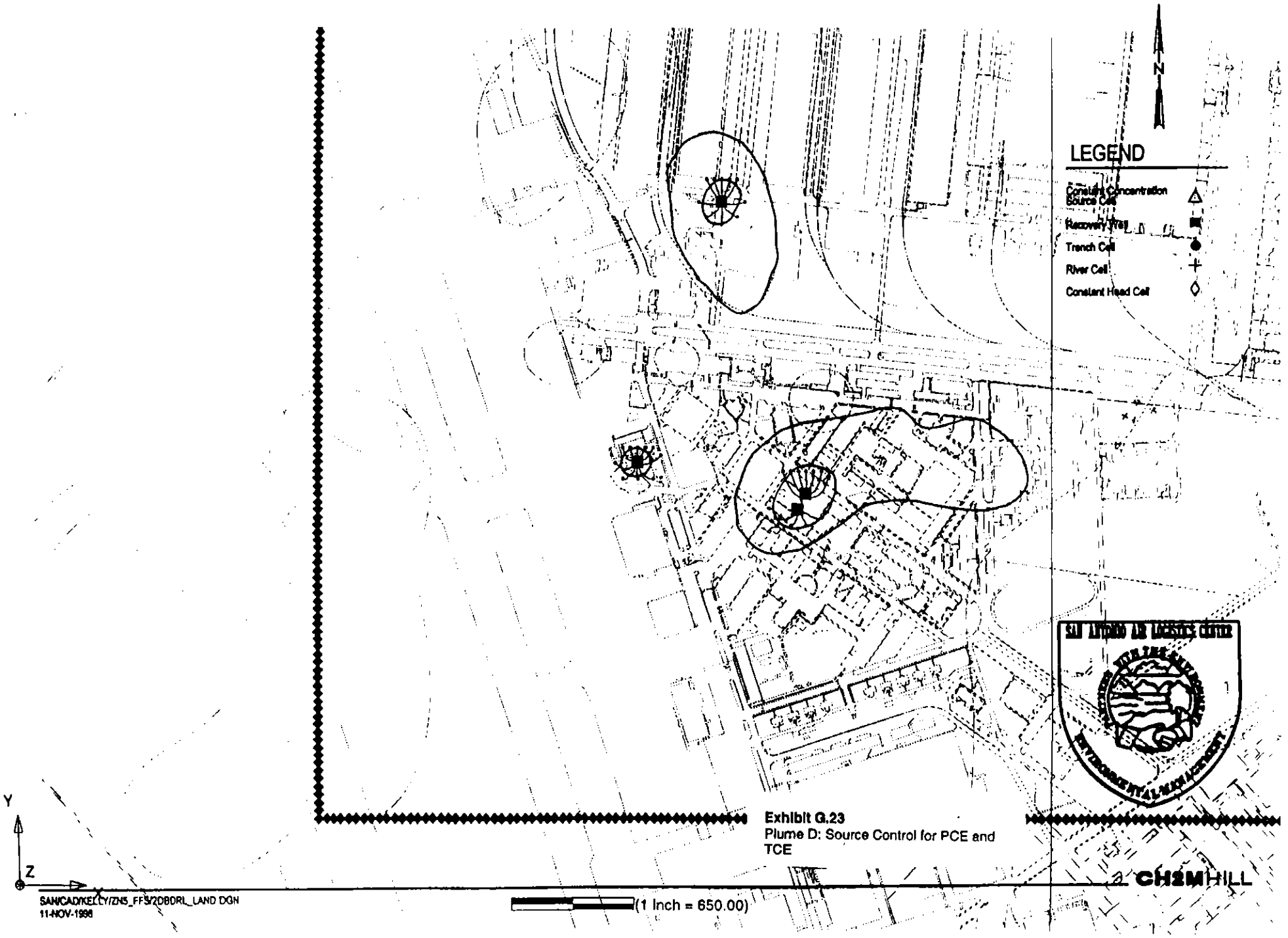


Exhibit G.23
Plume D: Source Control for PCE and TCE

SAN/CAD/KELLY/ZN5_FFS/2DBDRL_LAND.DGN
11-NOV-1998

CH2MHILL

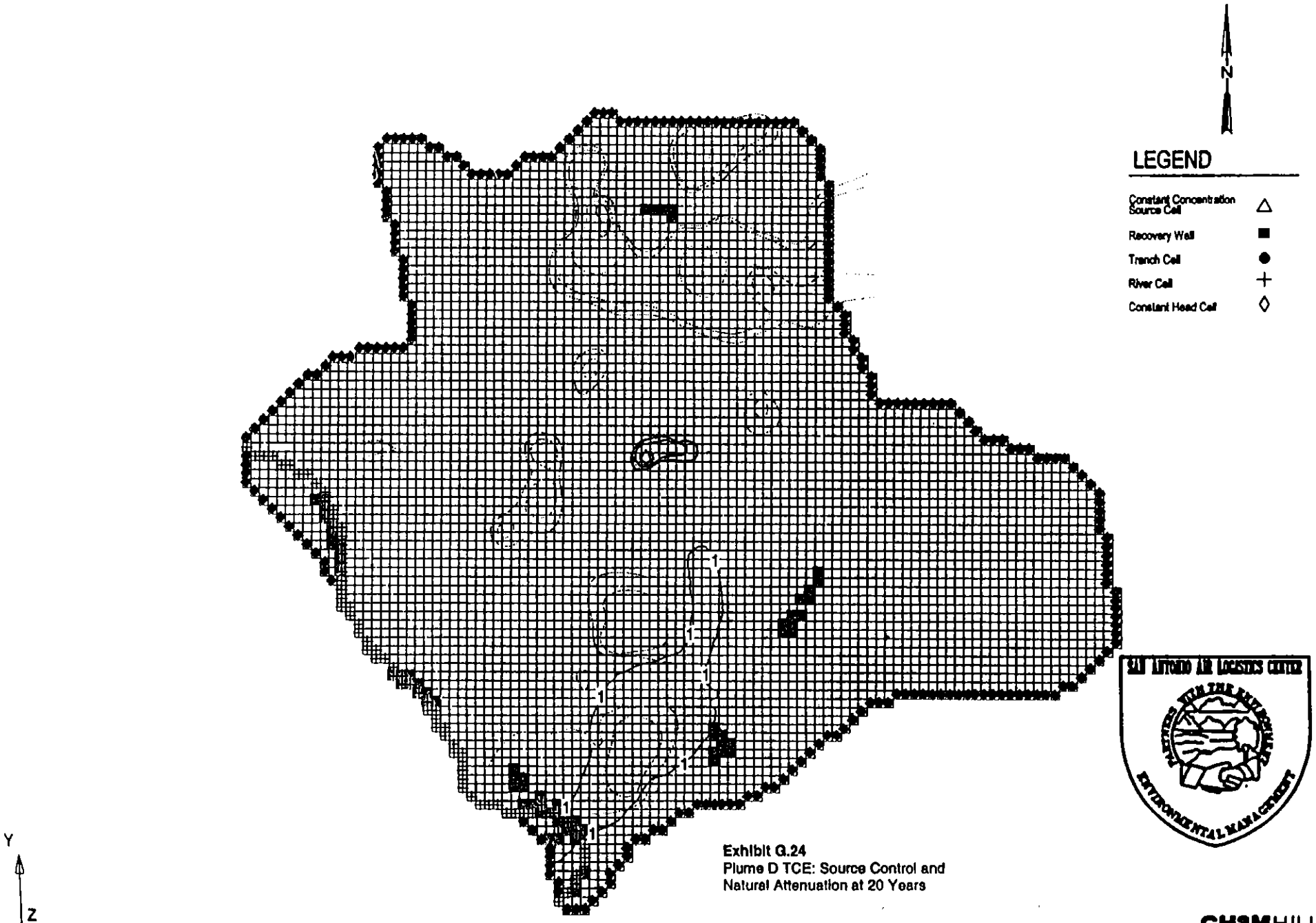


Exhibit G.24
Plume D TCE: Source Control and Natural Attenuation at 20 Years

SAN CADW LY/ZN5_FFS/20BDRL_LAND DGN
11-NOV

1 inch = 3000.00)

CH2MHILL

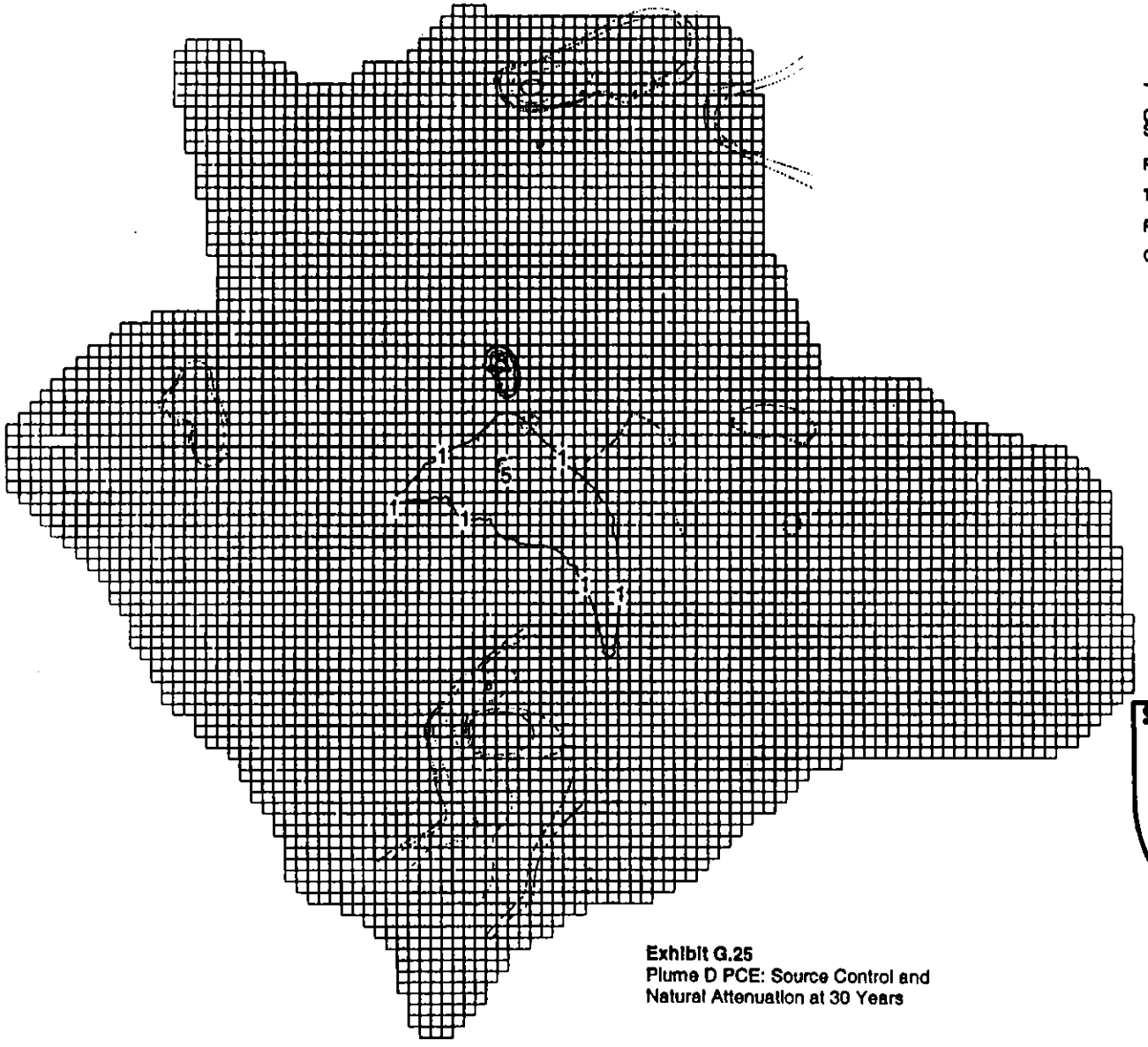


Exhibit G.25
Plume D PCE: Source Control and Natural Attenuation at 30 Years

Y
Z

SAN/CAD/KELLY/ZN5_FFS/2DBDRL_LAND.DGN
11-NOV-1998

(1 inch = 3000.00)

CH2MHILL

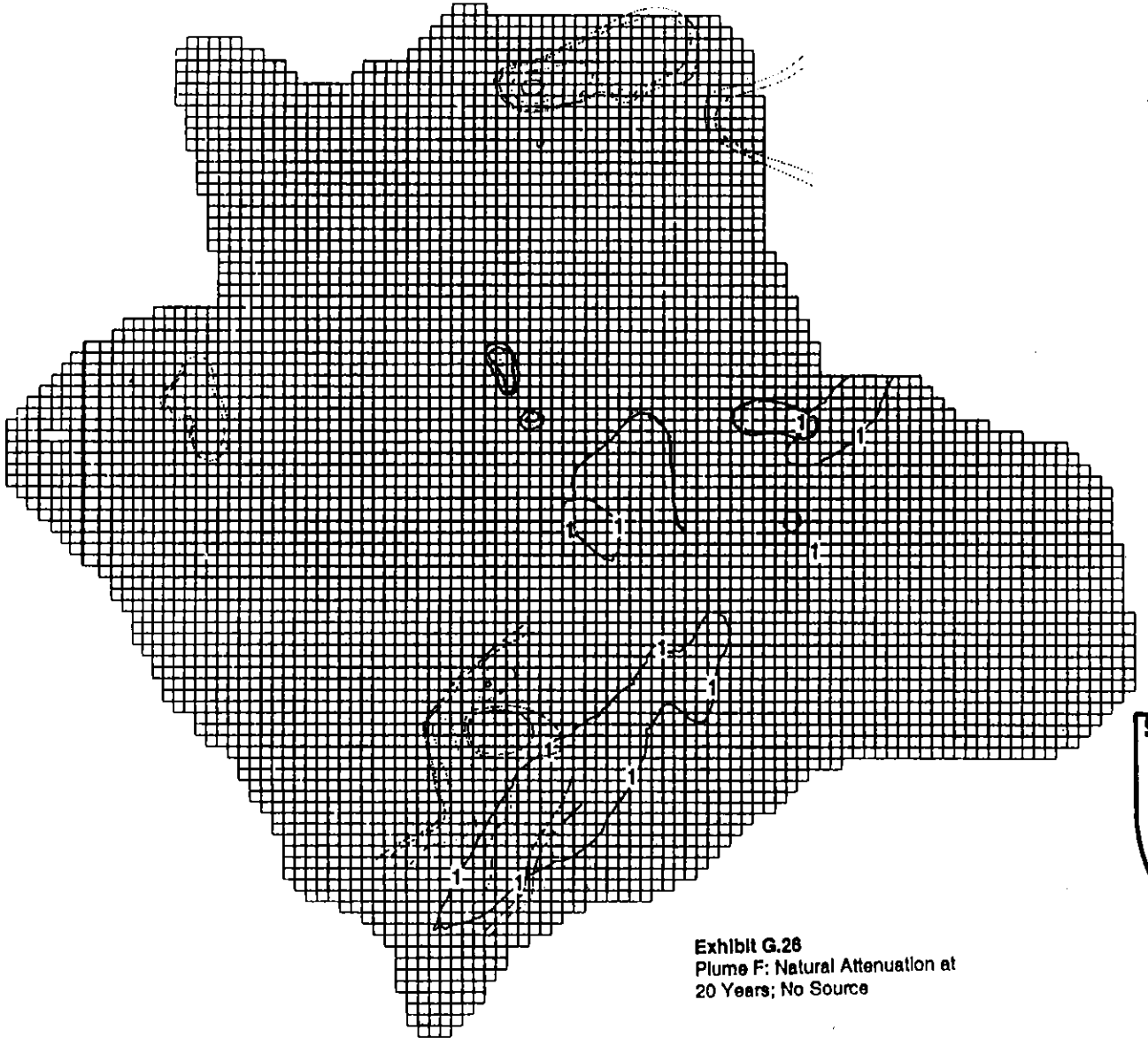


Exhibit G.26
Plume F: Natural Attenuation at
20 Years; No Source

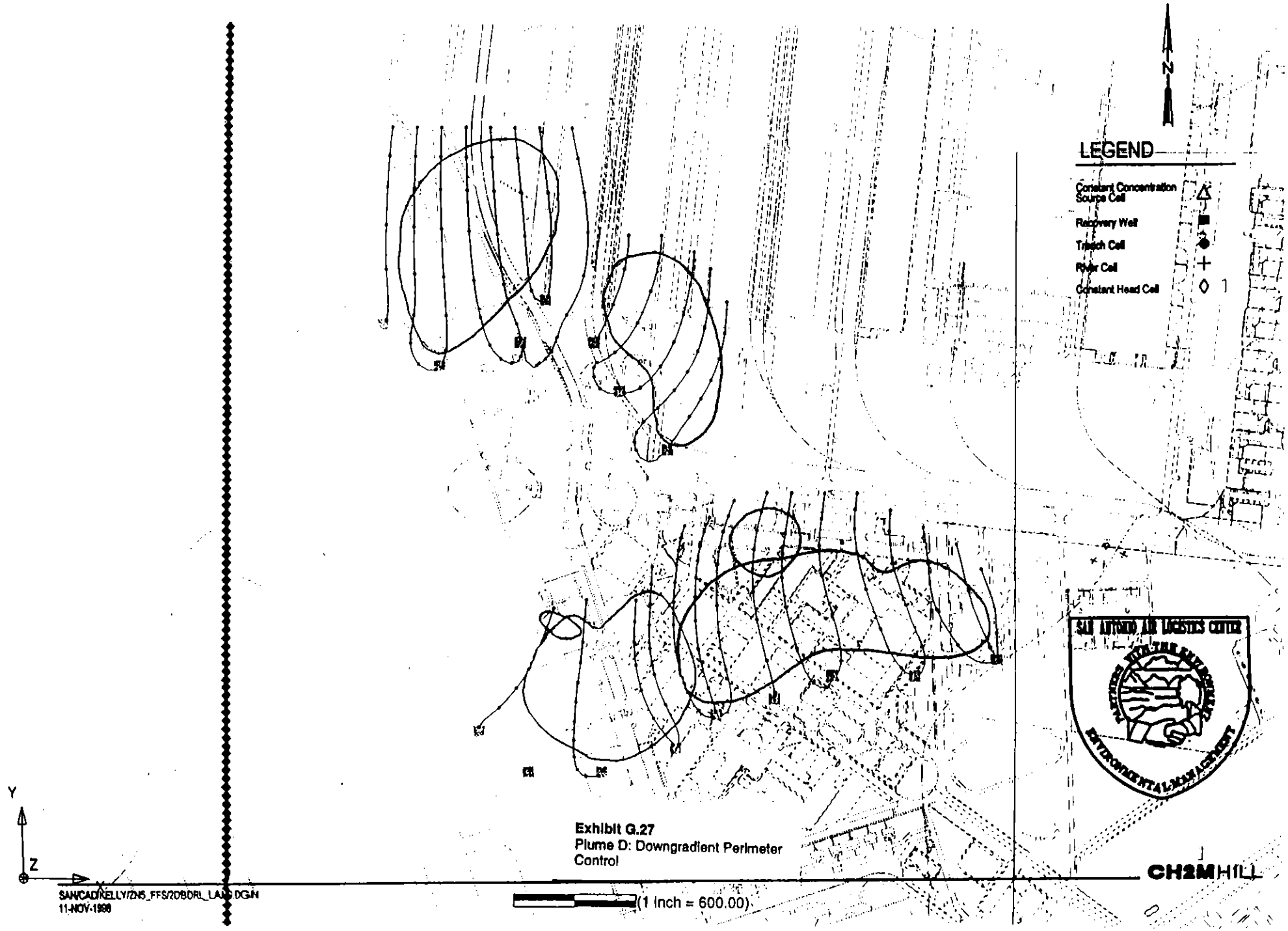


Exhibit G.27
Plume D: Downgradient Perimeter Control

SAN/CAD/KELLY/DN5_FFS/2DBDRL_LAN.DGN
11-NOV-1998

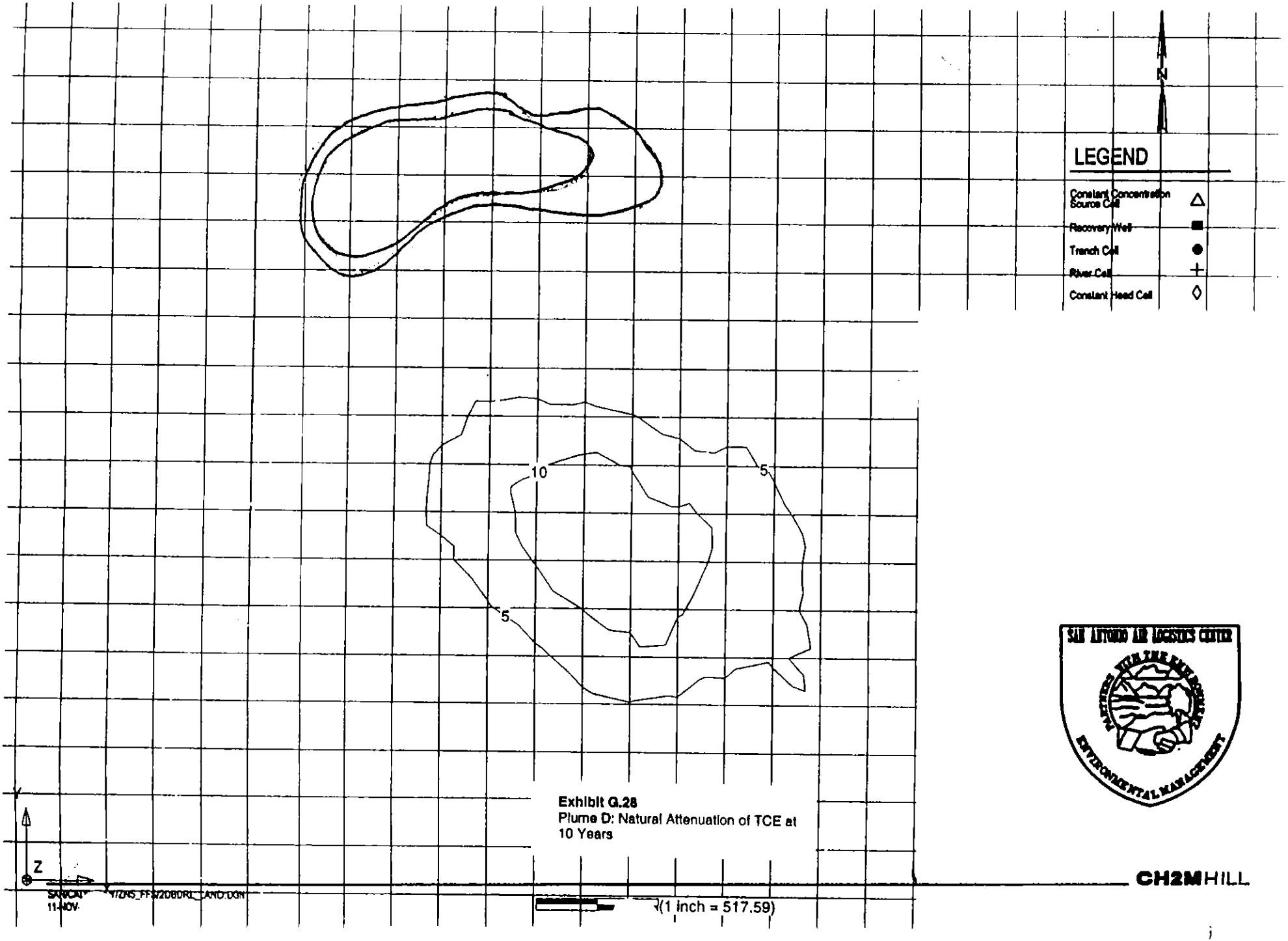


Exhibit G.28
Plume D: Natural Attenuation of TCE at 10 Years

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CH2MHILL

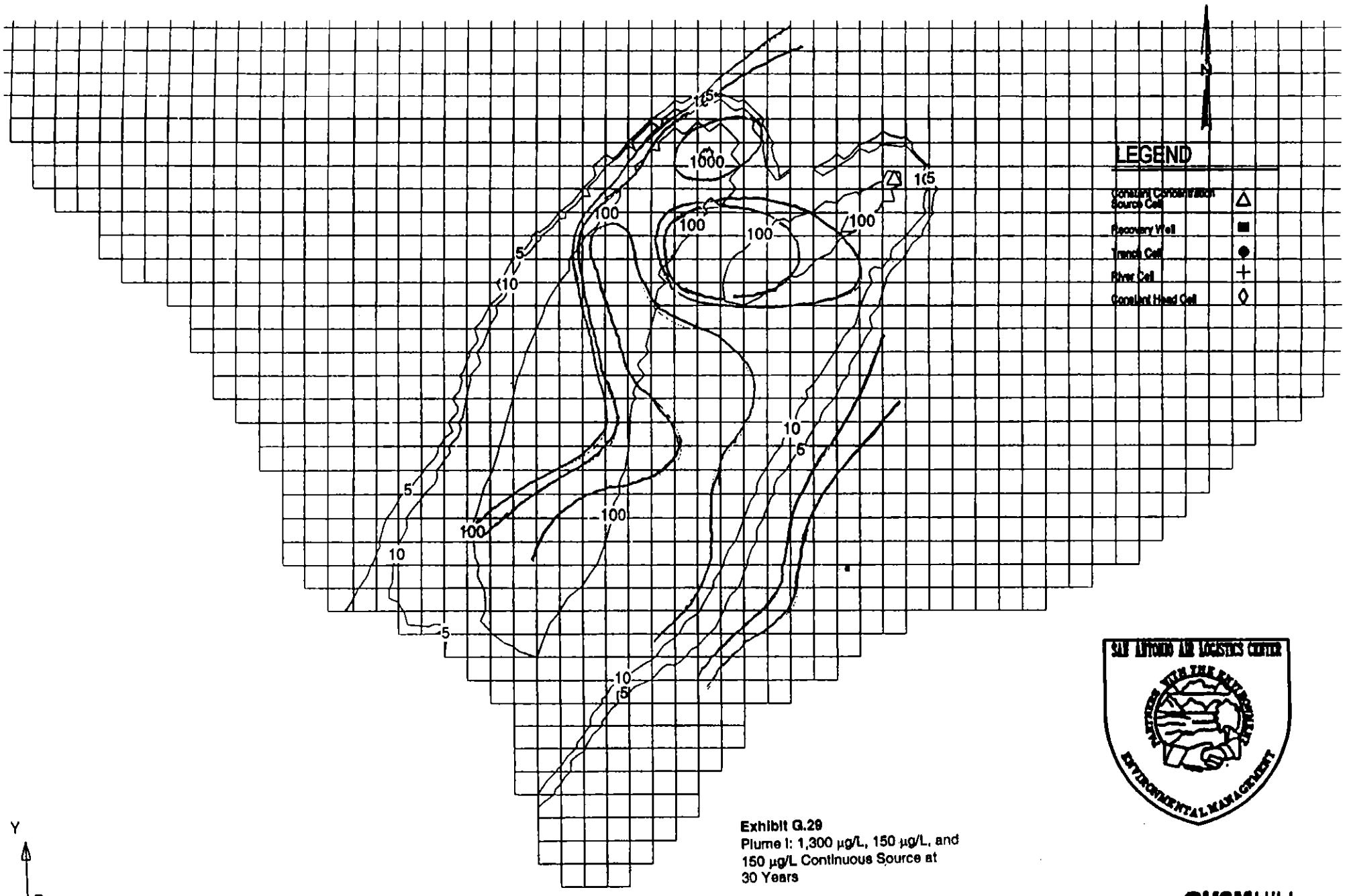


Exhibit G.29
Plume I: 1,300 µg/L, 150 µg/L, and 150 µg/L Continuous Source at 30 Years

SAN/CAD/KELLY/ZN5_FFS/2D80RL_LAND.DGN
11-NOV-1998

(1 Inch = 1100.00)

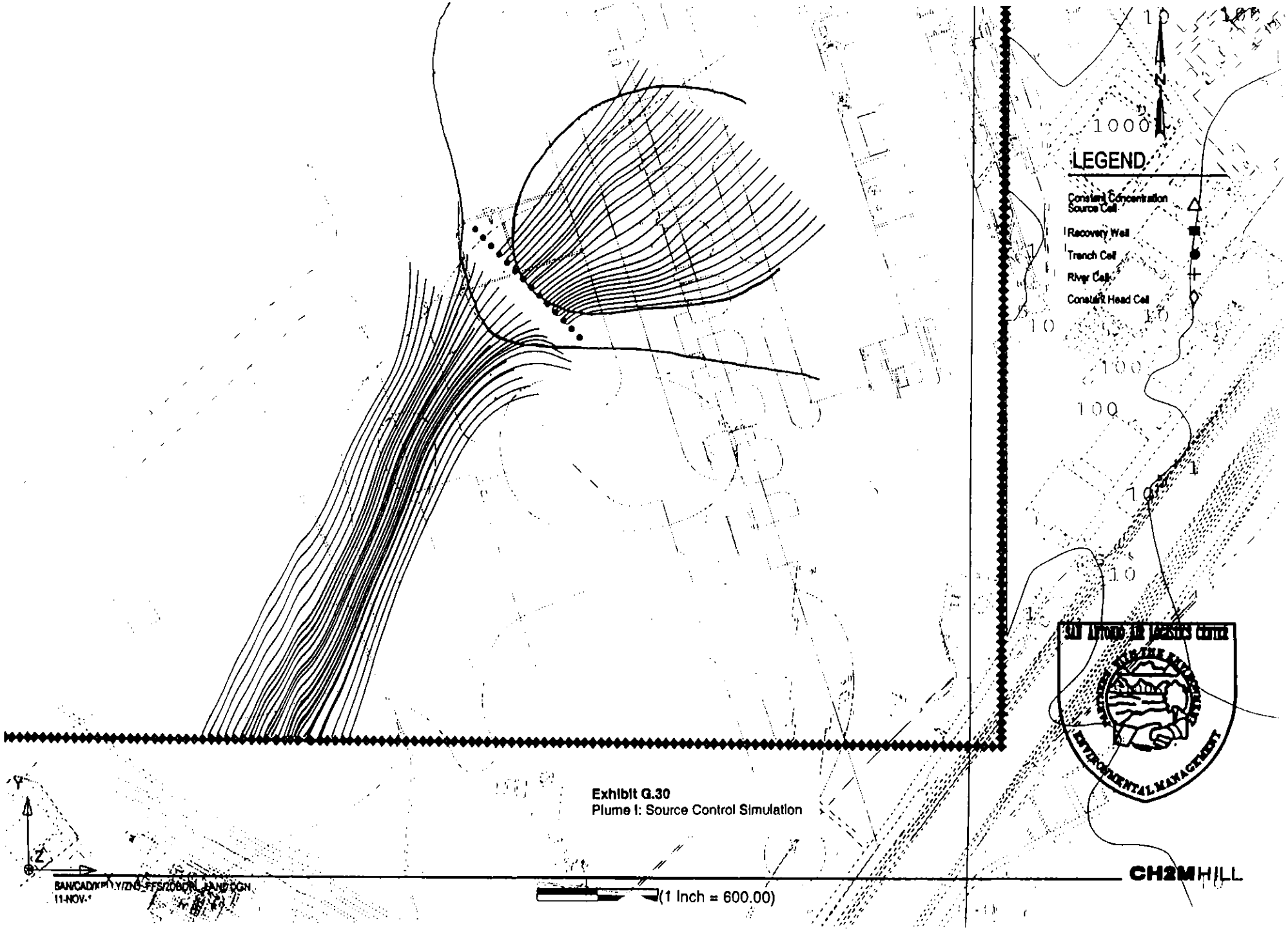
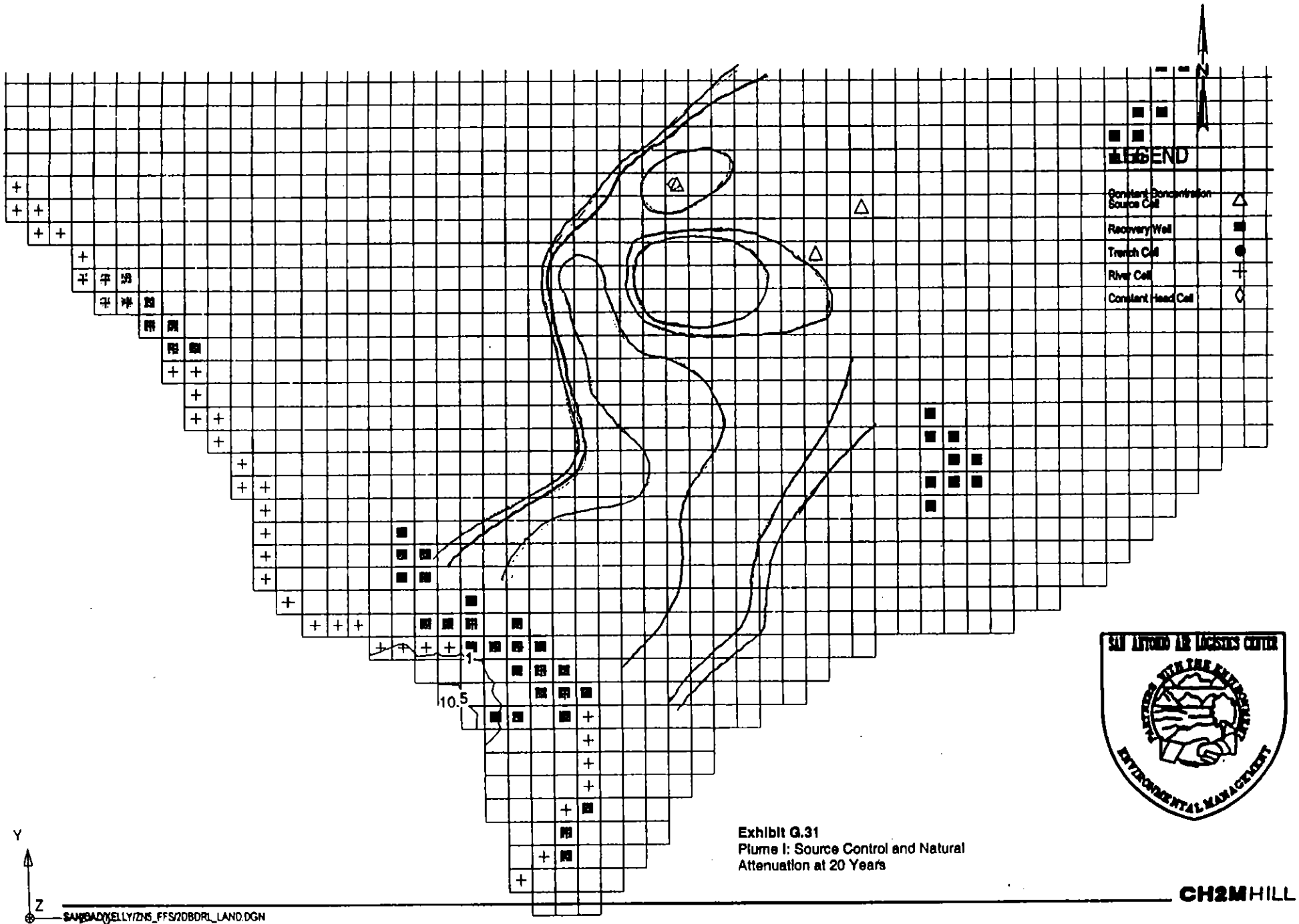


Exhibit G.30
Plume I: Source Control Simulation



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ENVIRONMENTAL MANAGEMENT

Exhibit G.31
Plume I: Source Control and Natural Attenuation at 20 Years

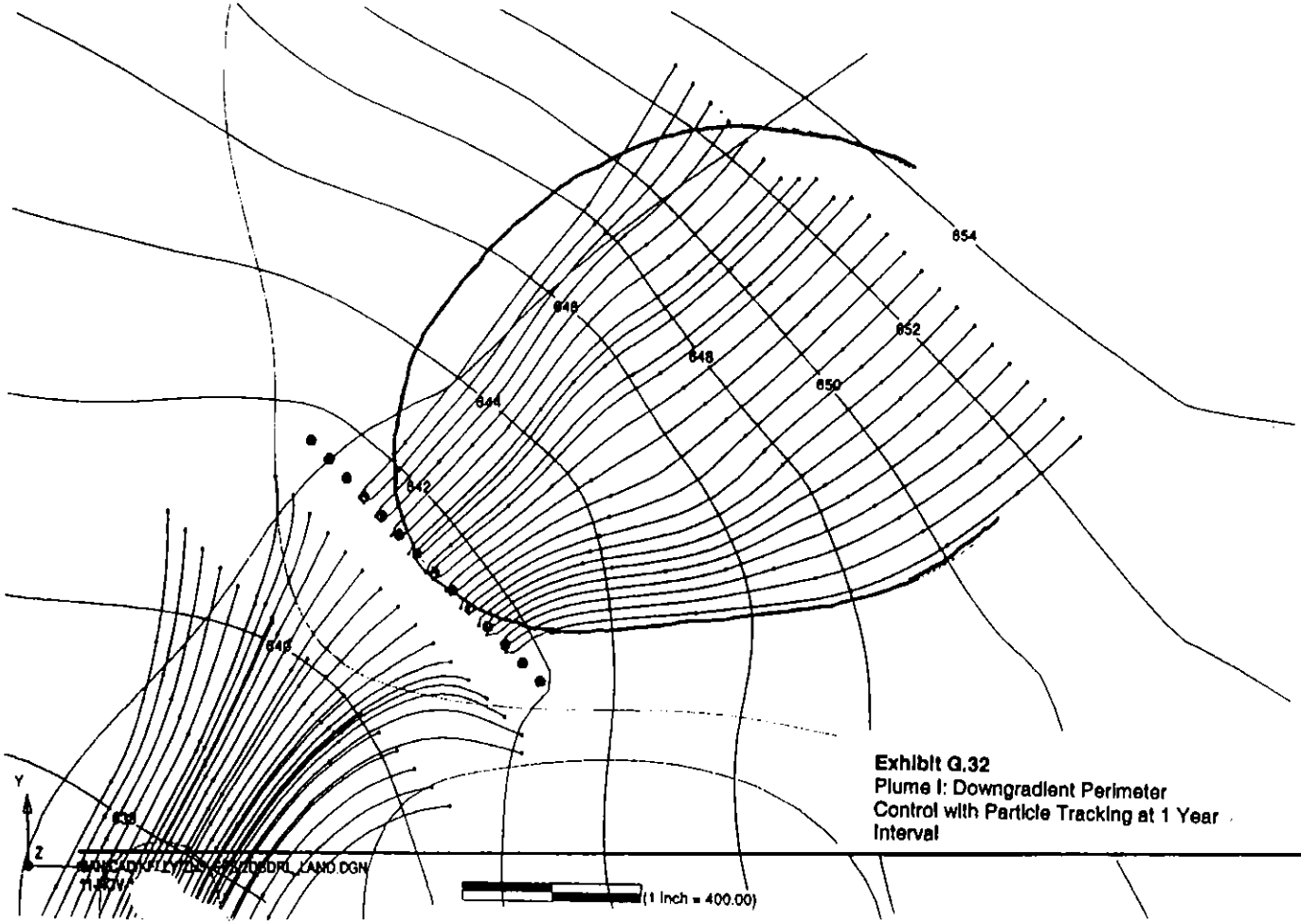


Exhibit G.32
Plume I: Downgradient Perimeter Control with Particle Tracking at 1 Year Interval

SAN ANTONIO AIR LOGISTICS CENTER
PARTNERS IN THE ENVIRONMENT
ENVIRONMENTAL MANAGEMENT

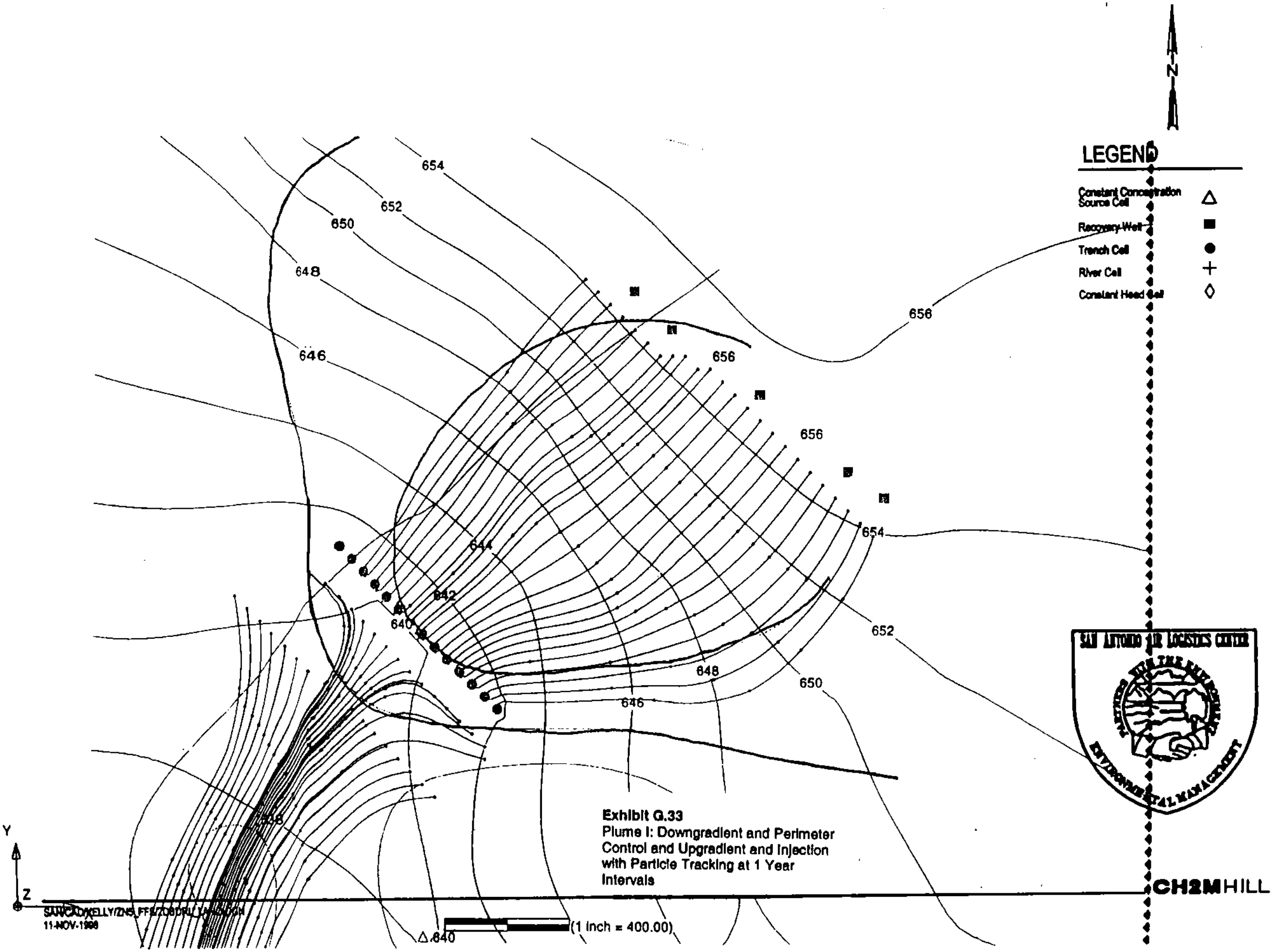


Exhibit G.33
Plume I: Downgradient and Perimeter Control and Upgradient and Injection with Particle Tracking at 1 Year Intervals

CH2M HILL

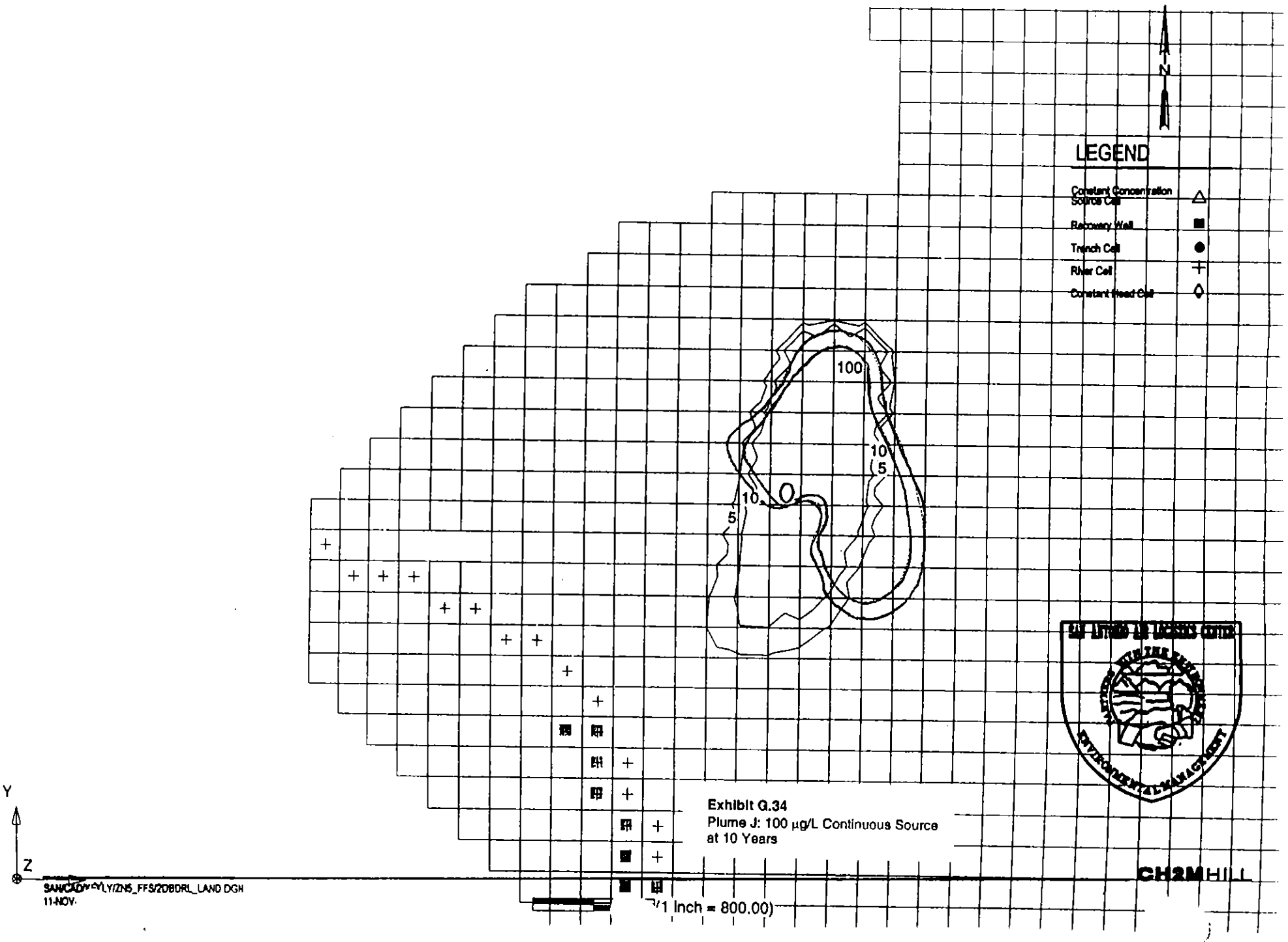


Exhibit G.34
Plume J: 100 µg/L Continuous Source at 10 Years

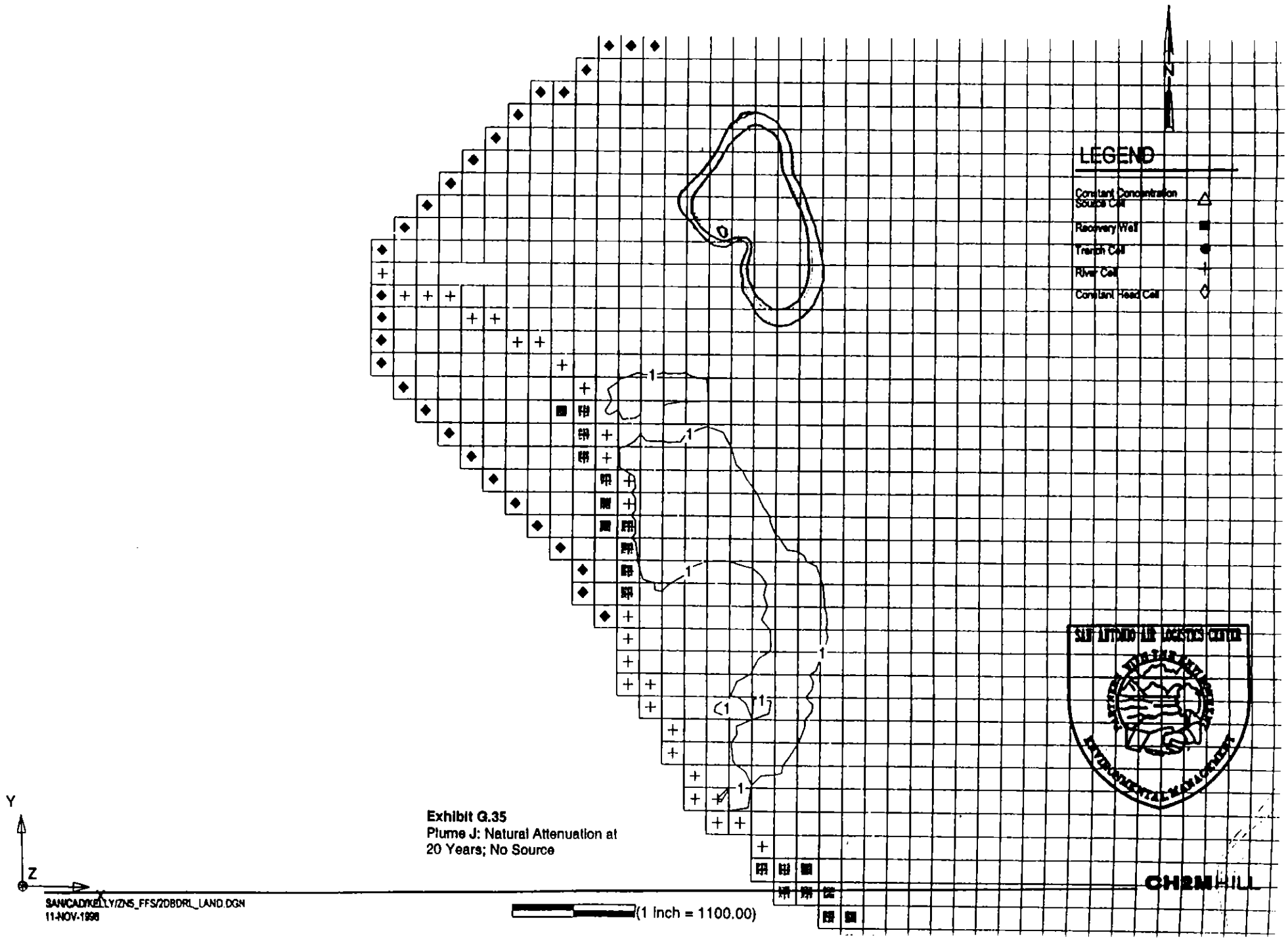


Exhibit G.35
Plume J: Natural Attenuation at 20 Years; No Source

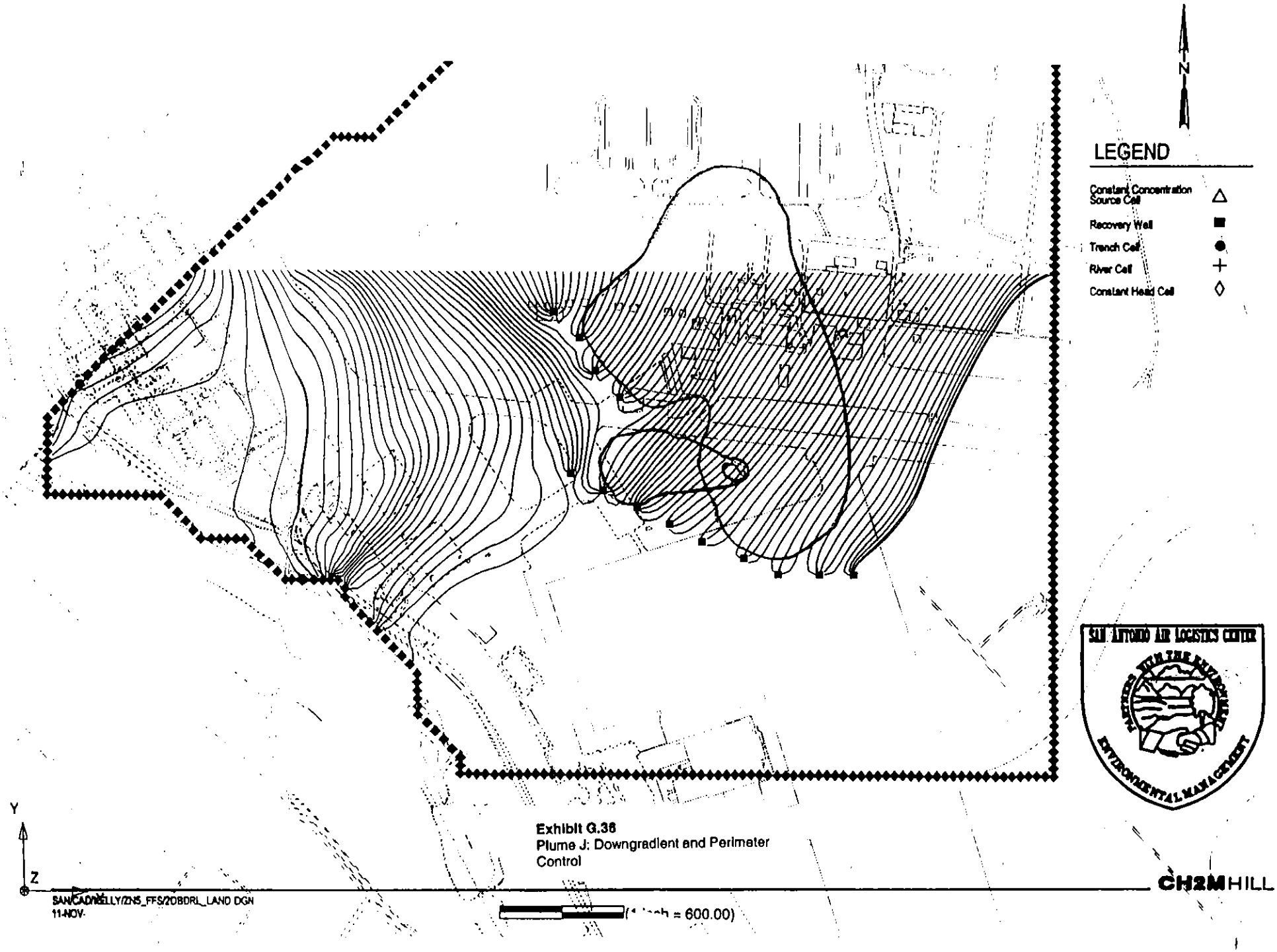
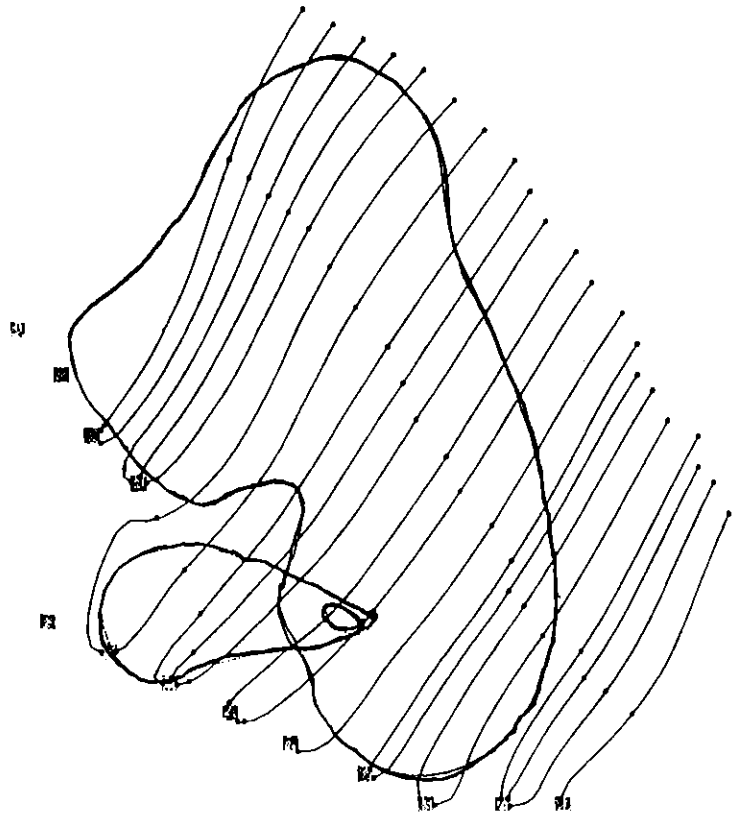


Exhibit G.36
Plume J: Downgradient and Perimeter Control



LEGEND

- Constant Concentration Source Cell
- Recovery Well
- Trench Cell
- River Cell
- Constant Head Cell

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WORKING WITH THE ENVIRONMENT
ENVIRONMENTAL MANAGEMENT

Exhibit G.37
Plume J: Downgradient Perimeter Control with Particle Tracking at 1 Year Intervals

Y
Z

SAN/COD/KELLY/ZN5_FFS/ZDBDRL_LAND.DGN
11-NOV-1998

(1 inch = 500.00)

CH2MHILL

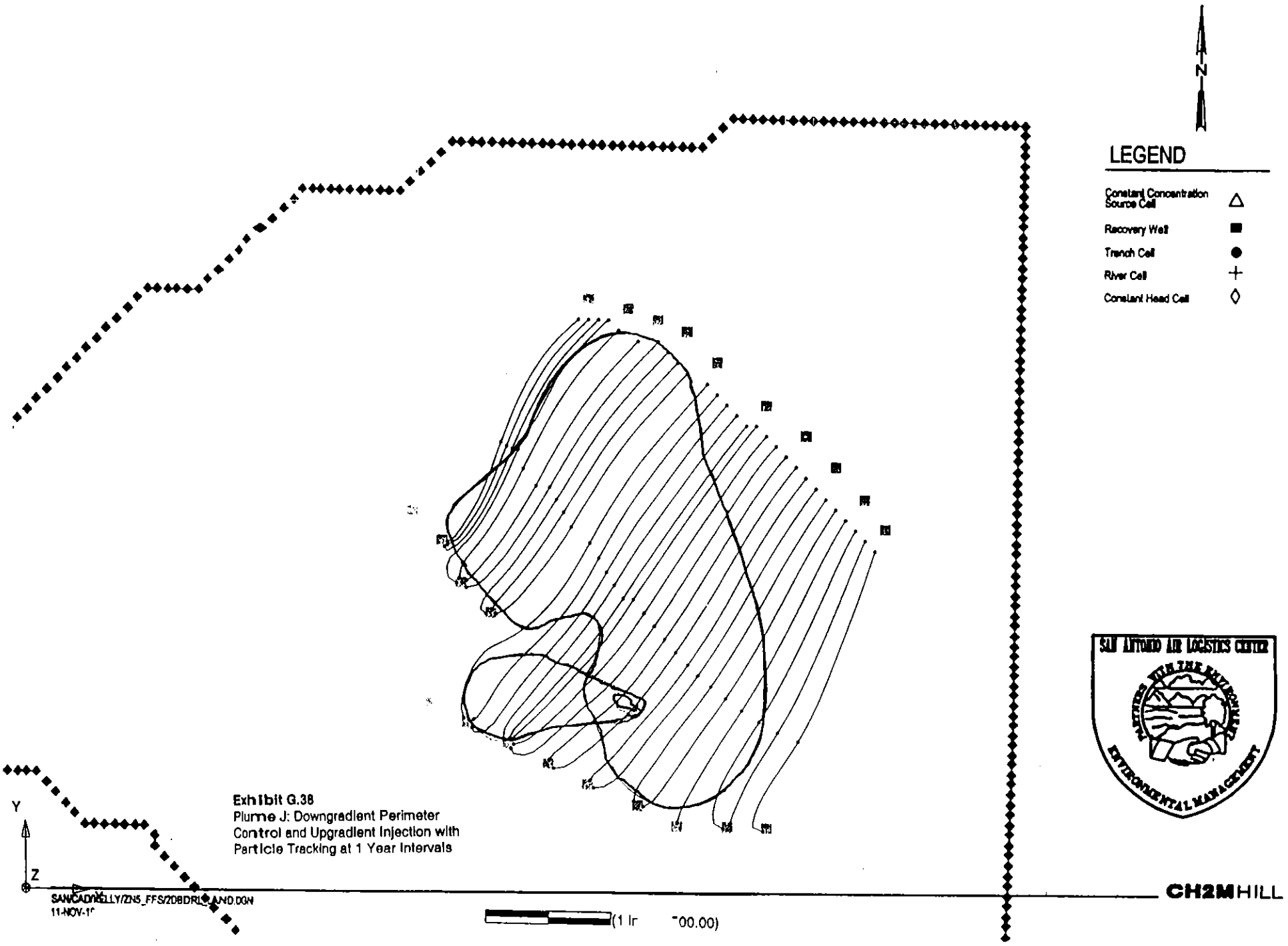
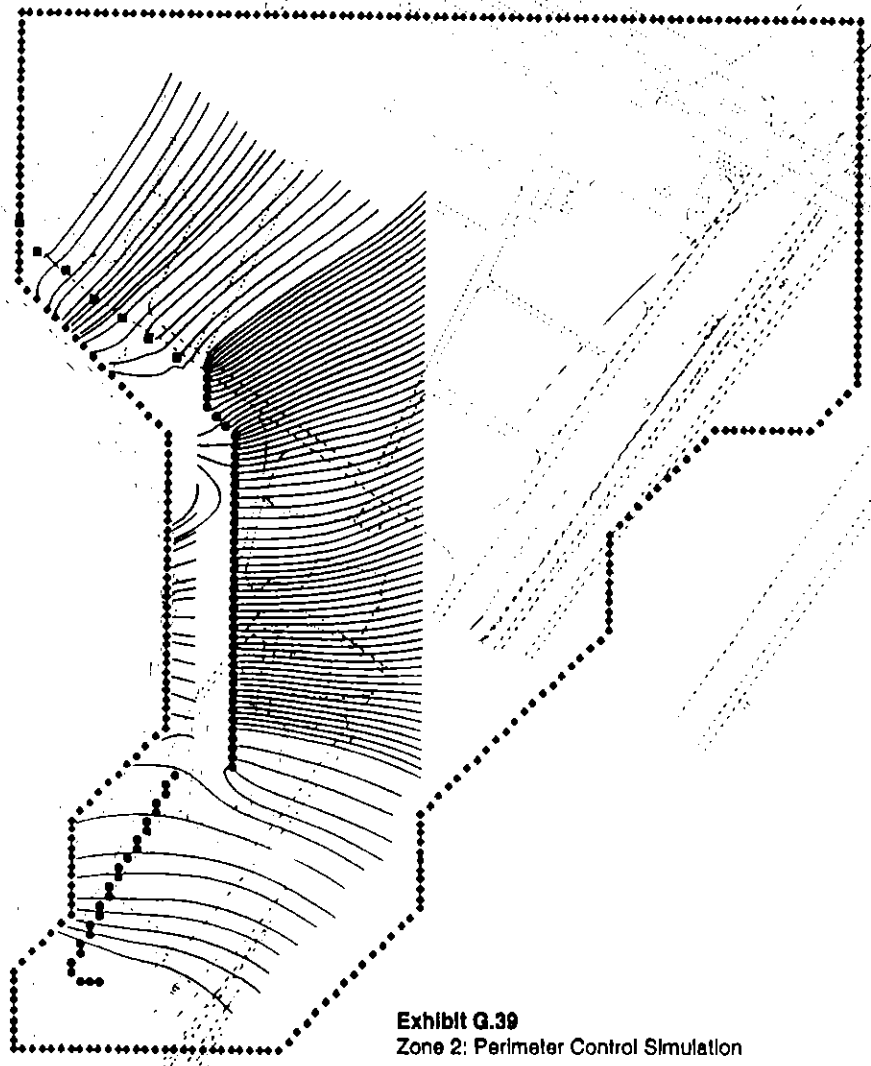


Exhibit G.38
Plume J: Downgradient Perimeter Control and Upgradient Injection with Particle Tracking at 1 Year Intervals



N

LEGEND

- Constant Concentration Source Cell
- Recovery Well
- Trench Cell
- River Cell
- Constant Head Cell

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MODFLOW Symbols

- Well
- Drain
- Constant Head

Exhibit G.39
Zone 2: Perimeter Control Simulation

Y
Z

(1 Inch = 400.00)

SAN/CAD/KELLY/ZN5_FFS/2DBDRL_LAND.DGN
11-NOV-1998

CH2MHILL

Appendix G2

HydroGeoLogic Groundwater Modeling Results

SIMULATION OF EXTRACTION SYSTEMS FOR ZONE 5 PLUMES AT KELLY AFB, TEXAS USING TRANSPORT ZOOM MODELS DEVELOPED FROM THE BASEWIDE GROUND-WATER FLOW MODEL

DRAFT FINAL

Prepared for:

Air Force Center for Environmental Excellence
Brooks AFB, Texas

Project No. MBPB98-7903
Contract F41624-95-D-8005-0017
Delivery Order 017

Prepared by:
HydroGeoLogic, Inc.
13740 Research Blvd. Suite N-5
Austin, Texas 78750

January 2000

EXECUTIVE SUMMARY

HydroGeoLogic is currently providing services, technical man-hours, and materials to perform ground-water fate and transport modeling at Kelly Air Force Base (AFB), Texas, in support of the Air Force Hazardous and Toxic Waste Programs. HydroGeoLogic maintains a calibrated basewide ground-water flow model from which detailed transport models can be developed for specific areas of the base.

HydroGeoLogic constructed and calibrated a basewide ground-water flow model (December-1997) for Kelly AFB in spring 1998. For the last two years (1998-1999), significant field data had been accumulated outside and within boundaries of the December-1997 model domain. Most of the new data was from the areas, which are not covered by the December-1997 model domain. The quality of calibration data set (such as water table, pumping rates, and recharge files) has been improved.

Based on the new data sets including the April 1999 water table, an expanded basewide flow model was constructed and calibrated. The April 1999 basewide mode results are consistent with the hydrological concepts established during the December-1997 basewide model construction. The residual statistics for hydraulic head and conductivity are within acceptable ranges. An excellent mass balance was achieved for the basewide model run.

Two refined zoom flow and transport models were developed for contaminant plumes designated as Plumes A, D, H, and J for the purpose of completion of a Corrective Measure Study (CMS) at Zone 5. Currently, there is no active remediation system pertained to these plumes. Ground-water recovery and Monitored Natural Attenuation (MNA) are proposed as remediation alternatives in the CMS report.

The following six extraction network systems were simulated for Plume A:

1) A 1,000 ft source-area trench, located immediately downgradient of the high Trichloroethylene (TCE) and Dichloroethylene (DCE) concentration area;
2) Perimeter trench (3,000 ft) along the base boundary;
3) Seven perimeter wells along the base boundary;
4) 12 off-base extraction wells located approximately 1,000 feet from the base boundary;
5) Source-area trench and perimeter wells, simulated concurrently; and
6) Source-area trench, perimeter wells, and off-base wells simulated concurrently.

For Plumes D-H-J, only one extraction system was simulated for each plume. These three plumes are considerably smaller than Plume A and unlike Plume A, they are completely contained within the boundaries of Kelly AFB. Four extraction wells are proposed for Plume D, which are placed next to the well points with elevated Perchloroethylene (PCE) or TCE concentrations. For Plumes H and J, eight and thirteen extraction wells respectively, are located downgradient from the front edge of the plumes.

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LIST OF ACRONYMS

AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
BRA	Basewide Remedial Assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMS	Corrective Measure Study
CMI	Corrective Measure Implementation
ERPIMS	Environmental Restoration Program Information Management System
DCE	Dichloroethylene
f_{oc}	fraction of organic carbon
fpd	feet per day
gpm	gallon per minute
gm/cm^3	gram per cubic centimeter
IRP	Installation Restoration Program
K	Hydraulic Conductivity
Kcal	Kilocalories
K_{oc}	Water/Organic Carbon Partition Coefficient
MCL	Maximum Contaminant Level
mg/L	milligrams per Liter
mg/kg	milligram per kilogram
mV	mili-Volts
ppb	parts per billion
PCE	Perchloroethylene
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
R_f	Retardation Factor
RI	Remediation Investigation
RMS	root-mean-square
SWMU	Solid Waste Management Unit
TCE	Trichloroethylene
TNRCC	Texas Natural Resource Conservation Commission
TOC	Total Organic Carbon
USEPA	U. S. Environmental Protection Agency

ug/L	micrograms per Liter
VC	Vinyl Chloride
VOC	Volatile Organic Compound
WPI	Waste Policy Institute

1.0 BACKGROUND

HydroGeoLogic is currently providing services, technical man-hours, and materials to perform continued ground-water fate and transport modeling at Kelly Air Force Base (AFB), Texas, in support of the Air Force Hazardous and Toxic Waste Programs. HydroGeoLogic maintains a calibrated basewide ground-water flow model from which detailed transport models can be developed for specific areas of the base. These models have been successfully used to evaluate remediation alternatives and to support Corrective Measure Study (CMS) and Corrective Measure Implementation (CMI) activities at Kelly AFB.

1.1 BASEWIDE GROUND-WATER FLOW MODEL

Based on a comprehensive understanding of geology and hydrogeology conditions at Kelly Air Force Base (AFB), HydroGeoLogic constructed and calibrated a basewide ground-water flow model for Kelly AFB in the spring of 1998. Because this basewide model was calibrated using hydrogeologic data collected up to December 1997, it will be called the December-1997 model. The December-1997 model report was submitted to the Texas Natural Resource Conservation Commission (TNRCC) and US Environmental Protection Agency (USEPA) Region VI in March 1999 (HydroGeoLogic, 1999a). Model simulations were performed using HydroGeoLogic's MODFLOW-SURFACT code. MODFLOW-SURFACT is a fully integrated ground-water flow and solute transport code based on the U. S. Geological Survey modular ground-water flow model, MODFLOW. Key aspects of the December-1997 basewide ground-water flow model are that:

- It is composed of four model layers that represent vertical heterogeneity in the alluvial aquifer.
- It simulates extraction wells, ground-water interaction with Leon Creek, aquifer recharge, and fluxes into or out of the model domain.
- It is calibrated to accurately represent slight changes in ground-water flow directions caused by seasonal fluctuations in water table elevations.
- It is constrained with hydraulic conductivity values that were estimated for all four-model layers at more than two thousand borelog locations.
- It accurately reproduces the ground-water pathways inferred from concentration plume data.

The basewide model calibration was performed using data fusion technology. This technology permits a wide range of hard and soft data to be used during the model calibration and supports efficient methods for model recalibration. The accuracy of the calibration model is directly related to the quality and quantity of the field data used for model calibration. Hence, the calibrated model is considered a work-in-progress. As

more field data is collected or corrected, particularly in the area with scarce data points in the basewide model, the updated basewide model can be improved on an as-needed basis.

1.2 REFINED FLOW AND TRANSPORT ZOOM MODELS

Aside from providing the capability to simulate the ground-water table at the regional scale, the basewide model provides a conceptual and numerical framework from which multiple zoom models can be developed to address local solute transport issues at Kelly AFB. As implied by its name, a zoom model is developed by zooming into a portion of the basewide model, extracting all of the existing model inputs and field data measurements within the zoom model boundaries, and then constructing a separate model by refining the numerical grid and inserting additional information. Zoom models may be utilized for specific areas such as a Solid Waste Management Unit (SWMU), a plume management area, a contaminant plume, or a remediation system.

HydroGeoLogic developed a refined flow and transport zoom model at Site S-4, Zone 3, in support of the S-4 CMS report. The model was used to evaluate five remediation alternatives for the removal of PCE, TCE, DCE, and VC. The remediation alternatives included extraction wells/trench, horizontal wells, natural biodegradation, enhanced in-situ biodegradation, and reactive walls. Detailed 30-year model simulations were provided for all four chlorinated solvents for each of the five remediation alternatives. Each simulation included adsorption, dispersion, and biodegradation. The first-order biodegradation rates for all four chlorinated solvents were developed based on site-specific data and were confirmed with model simulations. The Draft Final report: Evaluation of Remediation Alternatives at Site S-4, Kelly AFB Using a Ground-Water Flow and Transport Model was delivered to Kelly AFB on August 31, 1999 (HydroGeoLogic, 1999b).

This report consists of three main parts: Part 1 documents the expansion of the December-1997 basewide flow model. Part 2 describes the zoom flow model for Plume A and Plumes D-H-J in Zone 5. Part 3 applies the zoom transport models for evaluation of remediation alternatives in support of the Zone 5 CMS report.

2.0 CONSTRUCTION AND CALIBRATION OF EXPANDED BASEWIDE FLOW MODEL

The December-1997 basewide ground-water flow model has a numerical grid consisting of 300-foot x 300-foot grid cells in the horizontal plane and four equally spaced layers in the vertical. The model domain includes all of Kelly AFB and extends off base to the southeast. The code Hydro-FACT (HydroGeoLogic, 1997) was used to determine the calibrated model input parameters. The calibration of the December-1997 basewide flow model was based primarily on data in the Environmental Restoration Program Information Management System (ERPIMS) up to December 1997. Approximately 2,000 borehole logs and 1200 water table measurements from four monthly sampling events were used as input for the model calibration. Results from the model calibration using Hydro-FACT were then inputted in the code MODFLOW-SURFACT (HydroGeoLogic, 1998) to produce the calibrated model.

For the last two years (1998-1999), significant field data has been accumulated outside and within boundaries of the December-1997 model domain. Most new data was from the area that was not covered by the December-1997 model domain. The quality of the calibration data set (such as water table, pumping rates, and recharge files) has been improved. Plume A extends beyond the boundaries of the December 1999 basewide model. These aforementioned considerations make it necessary to expand the December-1997 model domain, and thus produce a new basewide model, based on updated data.

2.1 CALIBRATION DATA

The new basewide model was developed using an extension of the April 1999 water table data set, updated borelog information, representative pumpage rates for each remediation system, and a revised recharge rate for the golf course region near Leon Creek in west Kelly AFB.

2.1.1 Water Table Measurement

A composite data set for March 1996 and December 1997 water table measurements was used as the primary calibration targets for the December-1997 basewide model. There are only 343 data points (average of March 1996 and December 1997 water table) in that composite data set. A more extensive sampling event was conducted in March-April 1999 (referred to the April-1999 in this report). Ground-water elevation data from nearly one thousand wells were obtained during that sampling event with approximately one-third of measurements from newly installed wells to the east of Kelly AFB boundary.

Figure 2-1 shows a basewide contour map of hydraulic heads developed by kriging the point of April-1999 water table measurements. Kriging is a geostatistical method for data interpolation and contouring, which takes into consideration the spatial variance, location, and sample distribution in data. The kriging method is particularly useful in heterogeneous porous media when used to contour hydraulic heads. As shown in Figure 2-1, the highest hydraulic heads occur in the northwest corner of the Kelly AFB, which is

located on the center of the Navarro Ridge. From this northwest region, ground-water flows to the east, southeast, south, and southwest to Leon Creek. Ground-water also flows to the northeast from this mounding area. The basewide flow direction is similar to the general flow trends described in the previous model report (HydroGeoLogic, 1999a).

2.1.2 Borelog Data and Hydraulic Conductivity Calculation

Hydraulic conductivity values estimated from borelog lithology were used as the secondary calibration targets for the original basewide model. There are 2,166 borelogs used in the original basewide model. The following new borelogs were added to help calibrate the new basewide model:

42 borelogs associated with Site S-4 CMS work.
72 borelogs associated with Zone 5 RCRA Facility Investigation (RFI) and CMS activities.
Approximately 80 borelogs associated with off-base investigation east of Kelly AFB.

Figure 2-2 shows the location of approximately 2,300 borelogs contained in the new basewide model domain. Together with the water table measurements, this borelog data was used to develop the top and bottom surfaces for the ground-water model.

The lithologic units documented in the borelogs can be used to help constrain the model calibration. Each lithologic type needs to be assigned a representative hydraulic conductivity value. As part of the development of the basewide ground-water model, a detailed methodology was developed and used for calculating an average hydraulic conductivity value for each lithologic unit using results from slug and pumping tests. This methodology involved a regression analysis that used the geological log data and transmissivity results from over 300 well locations. The regression analysis was performed to select the set of hydraulic conductivity (K) values for the major lithologic units that would minimize the difference between the predicted transmissivity as calculated from the borelogs and the measured transmissivity values (from pumping and slug tests). The specific details associated with the regression analysis are provided in the basewide model report prepared by HydroGeoLogic (HydroGeoLogic, 1999a).

The estimated mean K for each lithologic unit is shown in Table 2-1. Except for the clay lithologic unit, the magnitude of the hydraulic conductivity values are within the ranges typically shown in text books and there is a trend of higher hydraulic conductivity values with an increase in the mean grain size. The 21 ft/day hydraulic conductivity assigned to the clay lithologic unit is attributed to the presumption that the clay classification includes a wide range of deposit types that span from 1-2 foot layers of a highly plastic clayey deposit to 3-5 foot zones of clayey deposits of sandy materials. As a result, the clay lithologic unit is considered to represent a deposit frequently characterized by silts and sands.

Because of the heterogeneous nature of the aquifer deposits, a large confidence level is associated with each of the mean K values. For instance, a mean K for the Clayey Gravel

is about 100 ft/day so the estimated range of the Clayey Gravel is about 20 to 500 feet/day. Although this range may seem large, these ranges are very similar to those that are derived for each lithologic based strictly on the field data. All K values in the model were bounded by the minimum and maximum values of 0.1 and 1000 ft/day. Using the information in Table 2-1, the lithologic profiles were transformed into continuous profiles of hydraulic conductivity values at approximately 2,300 borelog locations.

Because of the similar K values associated with three of the lithologic units (Clay with Sand Lenses, Silt, Sand) these units can be considered, for all practical purposes, as representing the moderate to low-K deposits at Kelly AFB. The Clayey Gravel and Gravel Units therefore represent the moderate to high-K deposits at Kelly AFB, respectively.

Table 2-1
Estimated Mean Hydraulic Conductivity (K) Values for the Major Lithologic Units Based on Results from the Regression Analysis for Basewide Simulations

Major Lithologic Units Description	Estimated Mean K (ft/day) Used in Basewide Model
Fill	62
Clay with Sand Lenses	21
Silt	20
Sand	33
Clayey Gravel	95
Gravel	349

2.1.3 Extraction Well Pumping Rates

Extraction rates for remediation systems were entered as a sink/source item for model calibration. Currently there is a flow meter for each extraction well associated with a remediation system. In addition, there is a flow meter that measures the cumulative pumping from all of the extraction wells in the remediation system. These flow meters are read at approximately monthly intervals. Pumping rates are calculated by dividing the total flow measured by the meters and by the number of days between measurements.

Waste Policy Institute (WPI) provided HydroGeoLogic with a spreadsheet that contains monthly total discharge readings for each extraction well at all remediation sites. For each well, monthly flow rates were calculated, tabulated, and averaged. Most systems existed data discrepancies, such as backwards flow meter reading, completely new flow meter numbers suggesting change/resetting of flow meters etc.; although these problems were more frequent with older data. Many of the well data had at least one or more monthly values that were much greater than the average values. Although some of the higher monthly pumping rates may have represented actual flow rates, those monthly values that exceeded the average value by more than a factor of ten were likely caused by errors associated with the measurement, and were considered outliers.

Because of potential problems with outliers and missing data, HydroGeoLogic reviewed the pumping rates for March, April, and May of 1999 in order to determine a representative pumping rate for the April-1999 basewide model. Table 2-2 provides total pumping rates in gallons per minute (gpm) for each remediation system used to develop the April-1999 basewide model.

Table 2-2
Calculated April 1999 Pumping Rates for Each Remediation System

Remediation System	Well Number	Pumping Rates (gpm)
S-1	6	1
CS2NB	12	10
D4	14	24
D5	3	2
E1	9	12
S-4	24	7
S-8	12	8
MP	3	53
Total	83	117

2.1.4 Recharge Rates

The following modifications were made for a recharge output file generated from the original basewide model calibration as an input file for updated basewide model calibration.

1) Developed recharge distribution data in the expanded model cells by extrapolating from the existing recharge zones due to similarities of land use patterns.

2) Calculated a recharge rate of 5.7 inch/year for a golf course near Leon Creek based on the meter reading of irrigation system in April 1999 divided by total area of the golf course.

2.2 MODEL CONSTRUCTION

Compared to the December-1997 basewide model, there is no major change of the April-1999 flow model framework in term of its, discretization scheme, vertical structure of its model layers, hydraulic boundary assignment, and interaction with the Leon Creek. However, there is significant expansion of the model grid to the east resulting in a 12% increase of the active cell from 4,594 to 5,149 per each model layer. Figure 2-3 shows the December-1997 model domain and the April-1999 model active cells overlaid on a map of Kelly AFB. Figure 2-4 shows the total thickness of the model layers.

The vertical location of each model layer was selected to accurately represent the vertical differences in the aquifer materials. The lower two layers (layers 3 & 4) are associated

with coarse-grained deposits (high K) and the upper two layers (layers 1 & 2) are associated with moderate to fine-grained deposits (low K).

2.3 CALIBRATION RESULTS

Model calibration is a process of refining the model representation of the hydrogeological framework, aquifer hydraulic properties, and boundary conditions until one achieves a desired correspondence between the model simulation and measured field data. The new basewide model calibration primarily focused on reproducing 975 hydraulic head measurements, over 3,000 estimated hydraulic conductivity values from over 2,000 borehole logs, and several ground-water flow paths inferred from contaminant plume data. After grid assignment, there are 553 head points and 6,061 hydraulic conductivity points as calibration targets. The primary model parameter that was adjusted during model calibration was the hydraulic conductivity field.

An inverse modeling code (Hydro-FACT Version 2.1) based on data fusion technology was used for model calibration. Input to Hydro-FACT included measurements of hydraulic head, estimates of hydraulic conductivity, and inferred flow directions from Plume configurations. All of these measurements included both targeted values and estimates of their uncertainties. Benefits of using an inverse modeling code for calibration are described in the basewide flow modeling report (HydroGeoLogic, 1999a).

The recharge distribution produced by model calibration based on the April-1999 water table measurements is similar to previous basewide model results. The average recharge is about 2 inches/year. The highest recharge (6.4 inch/year) occurs in the area of Leon Creek golf course.

2.3.1 Hydraulic Head

Figure 2-5 shows hydraulic heads in Model Layer 3 of the April-1999 basewide model. Model Layer 3 contains the most transmissive aquifer materials. For most of the model domain, the hydraulic heads among the four layers differs less than 0.1 ft. For all practical purposes, Figure 2-5 represents the average hydraulic head contours for the aquifer. In order to help evaluate the accuracy of the calibrated model, Figure 2-6 shows the differences between the measured and predicted hydraulic head values for all four model layers. This difference is often referred to as a residual.

A useful statistic that represents an average deviation is the root-mean-square (RMS). A RMS for the residuals is calculated by dividing the square root of the sum of the square values of residuals by the number of values. For the 553 head points shown in Figure 2-6, the RMS is 1.22 feet. This RMS value is less than 2% of range in hydraulic head values across the basewide domain. Typically a RMS less than 5% of the head drop across a domain is acceptable.

Another useful statistic is the average bias. The average bias of 0.04 ft was calculated for the residuals by dividing the sum of residuals by the number of residuals. Such a small

value indicates there is very little bias associated with the calibrated model. Since the residuals in Figure 2-6 are calculated by subtracting the measured from the predicted value, the positive sign indicates that the model has a slight tendency to overpredict the hydraulic head measurement.

2.3.2 Hydraulic Conductivity

Figure 2-7 shows a three dimensional representation of the hydraulic conductivity field via fence diagrams. The continuity of lenticular and sheet-like low-K and high-K deposits is apparent in the fence diagrams across most of the model domain. The absence of heterogeneity in the eastern region of the model is attributed to a lack of borehole data to guide the K-field construction during model calibration. Zones of high-K (>500 ft/day) deposits appear to be continuous at distances of greater than 1,000 feet in the horizontal.

The differences between the targeted K values, which were derived from the borelog descriptions, the mean K values for each lithologic unit, and the K values in the calibrated model comprise the set of K residuals. Figure 2-8 shows the residuals in natural log (Ln) scale for the 6,061 hydraulic conductivity calibration targets by layer. The RMS for Ln K match is 1.66. The distribution of over and under estimations is relatively uniform. Layer 4 has the highest percentages of large residuals. These residuals are likely caused by the uncertainties associated with locating the surface of the Navarro Clay.

2.3.3 Water Budget

Table 2-3 summarizes the ground-water fluxes into and out of the basewide model domain. Positive values represent gains to the aquifer while negative numbers represent losses to the aquifer. The positive recharge flux represents the net amount from rainfall that reaches the water table. The negative recharge flux represents discharge at the model surface along seepage faces, most of which occur near Leon Creek. The well flux represents the total pumping of all 83 wells in the model domain. The river flux represents the gains and losses along Leon Creek. The model boundary fluxes include the amount of ground-water that is entering and leaving the sides of the model through the model's boundary cells. The model was solved for steady-state flow with a mass balance error of 0.14 %.

Table 2-3
Ground-Water Fluxes (ft^3/day) Calculated by the Basewide Model

Basewide	Recharge	River	Well	Model Boundary	Total Flux
In	139570	8143	0	42288	190001
Out	3212	53978	22171	110900	190261
Net	136358	-45835	-22171	-68612	-260
Mass Balance					0.14%

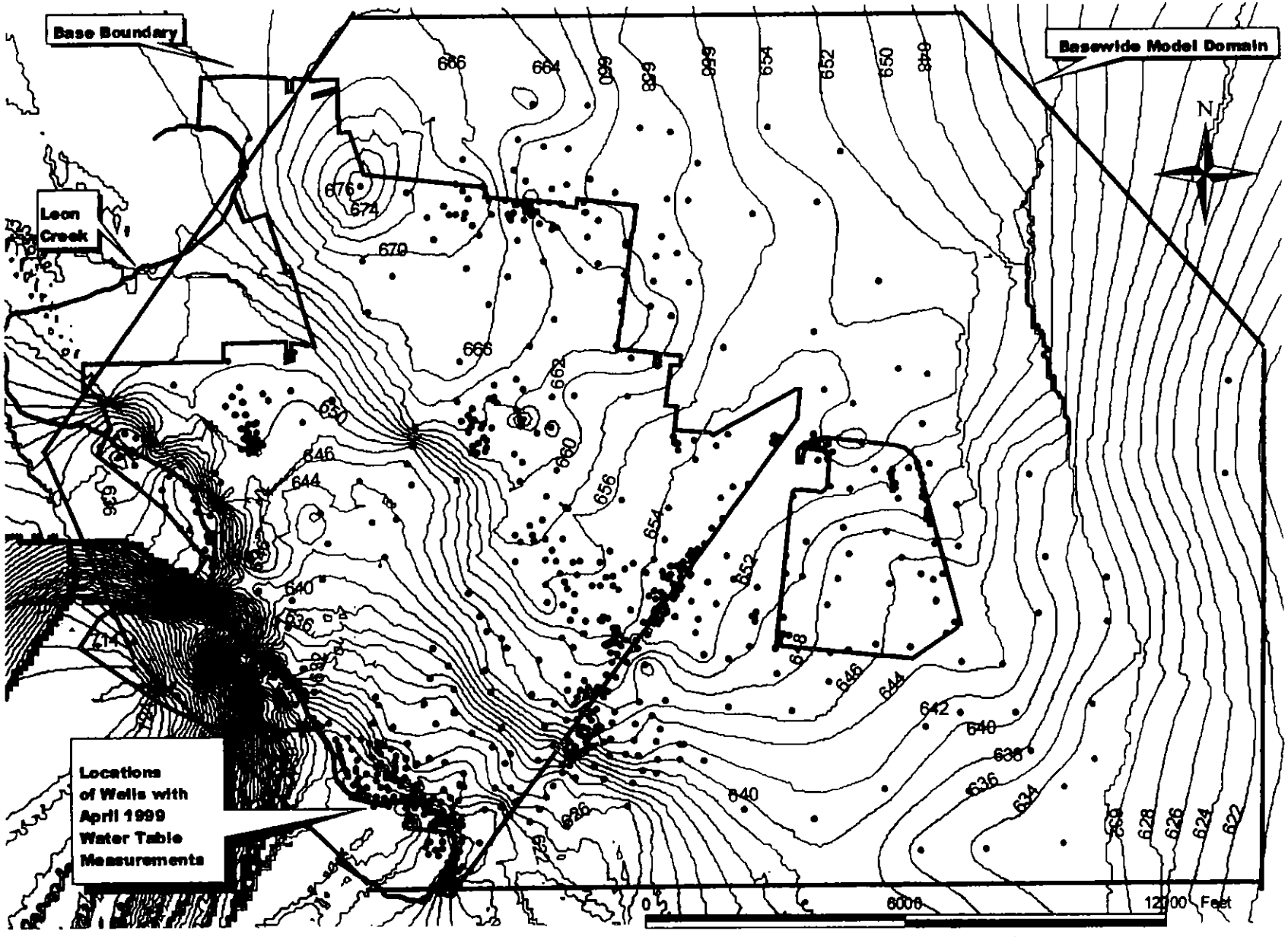


Figure 2-1 Kriged Contours of the April 1999 Hydraulic Head Data

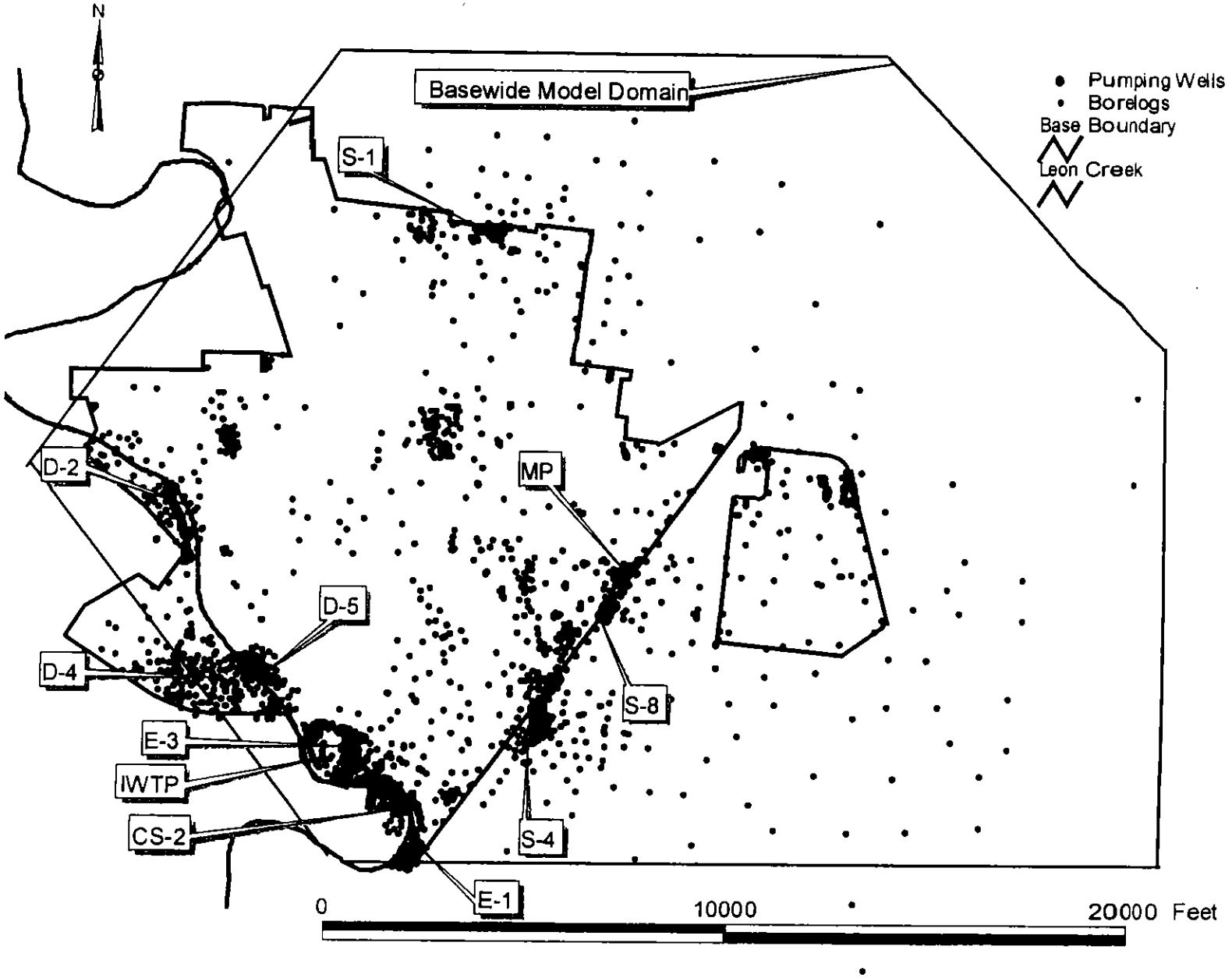


Figure 2-2 Locations of Borelogs and Extraction Systems Used to Develop the April 1999 Basewide Model Calibration

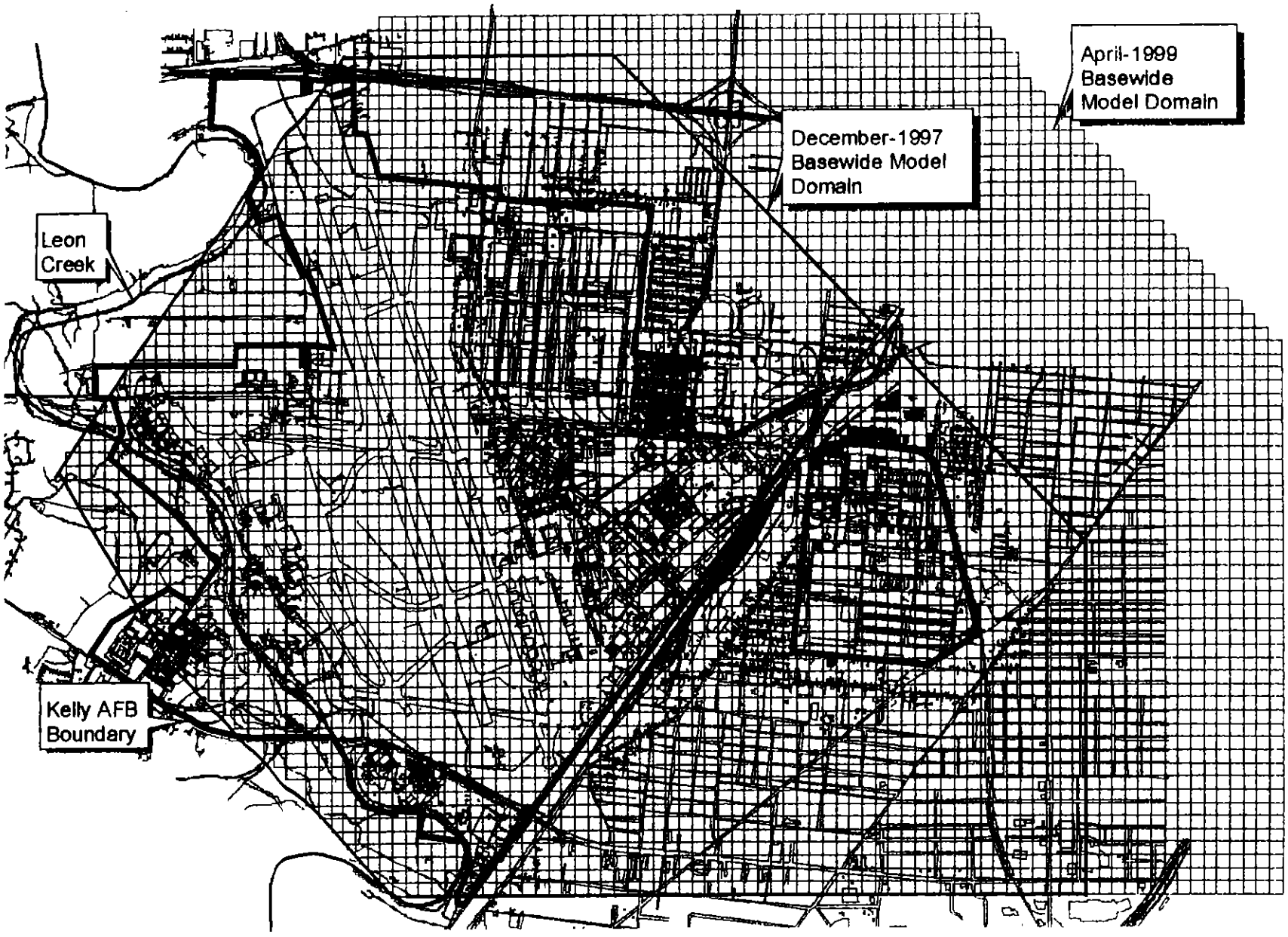


Figure 2-3 Numerical Grid of the April-1999 Basewide Flow Model Compared to the December-1997 Basewide Model Domain

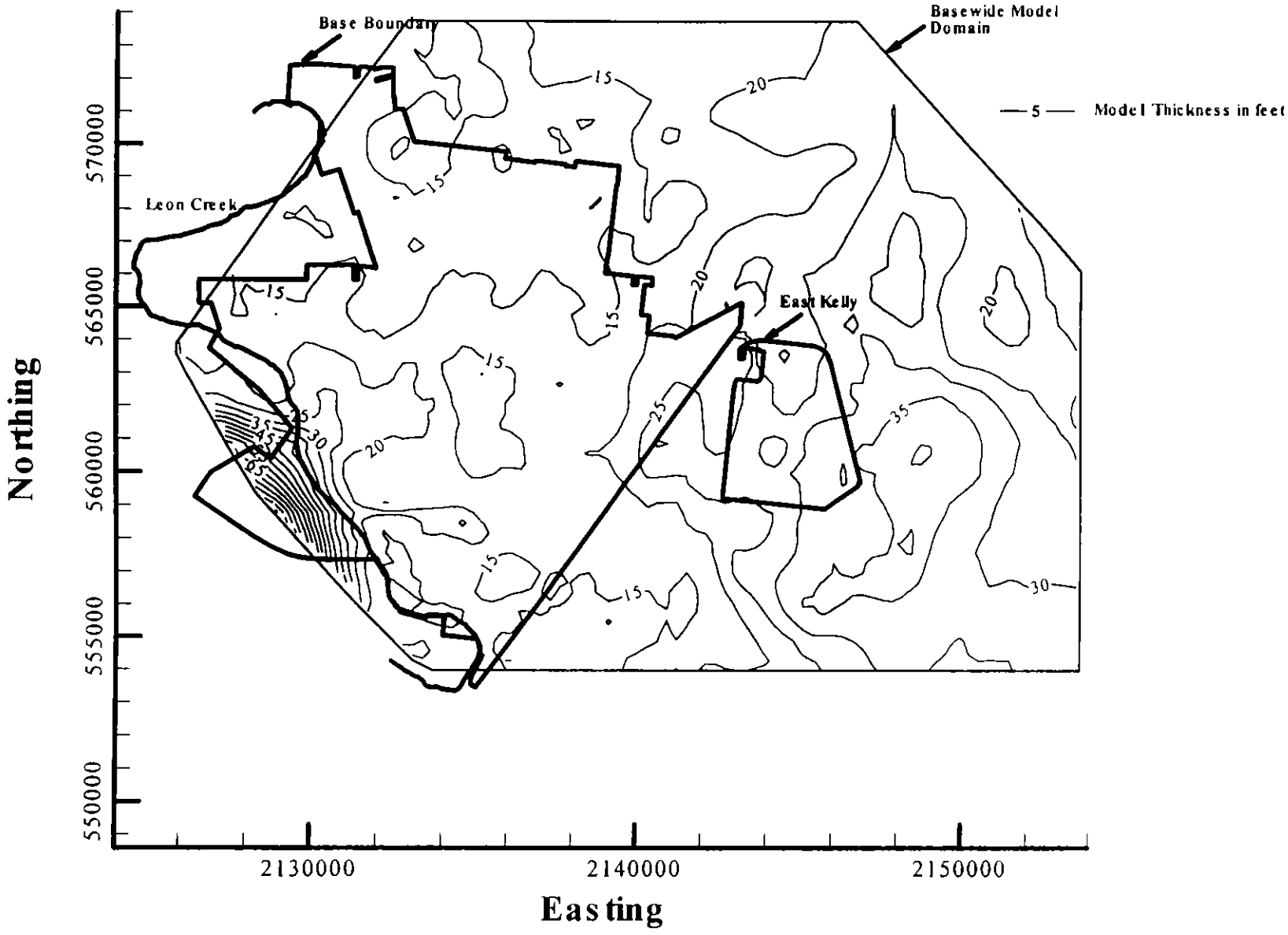


Figure 2-4 Total Thickness of the Four Model Layers Used in the April-1999 Basewide Model

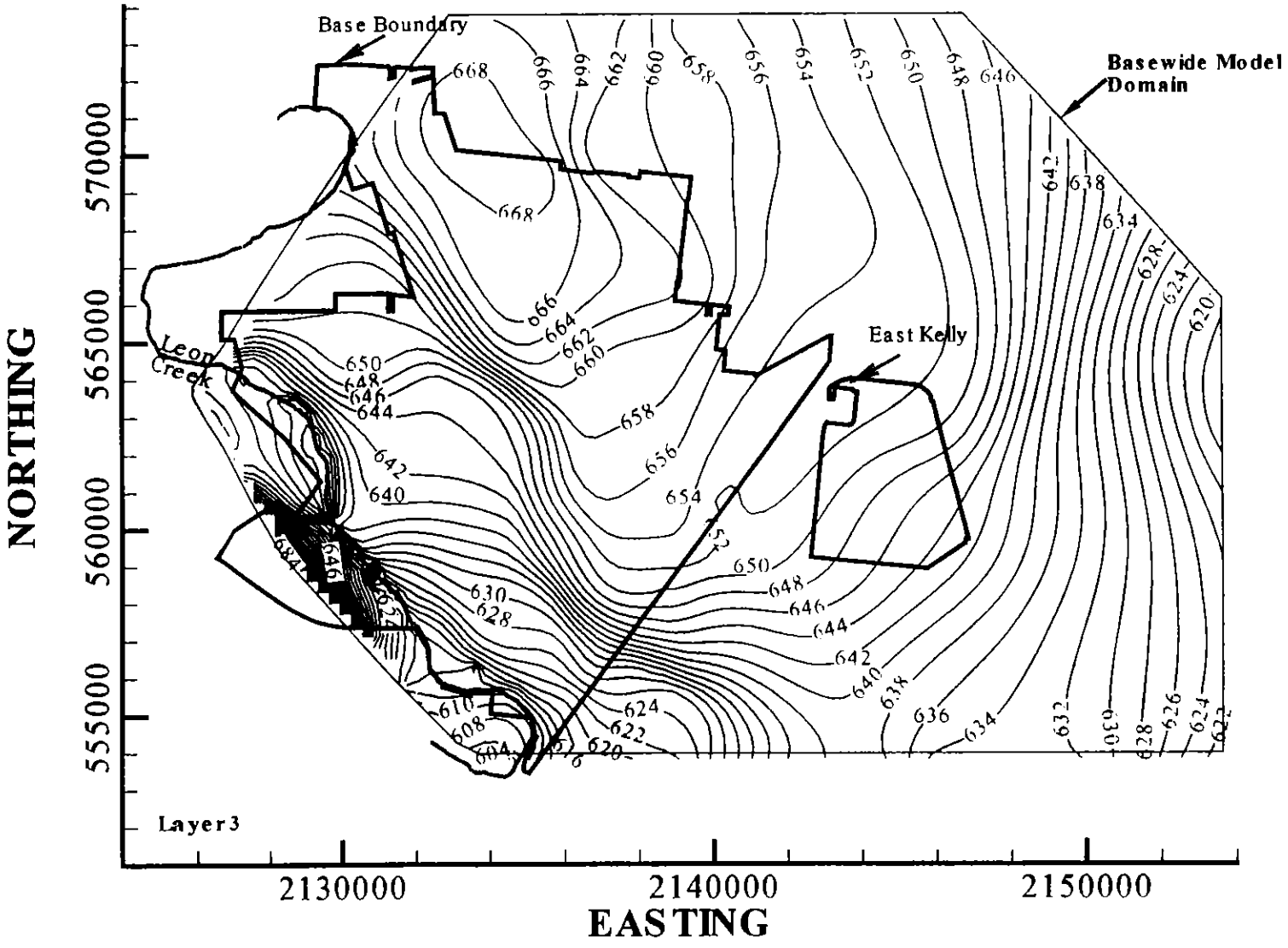


Figure 2-5 Contours of Hydraulic Heads Produced by Basewide Model Calibration

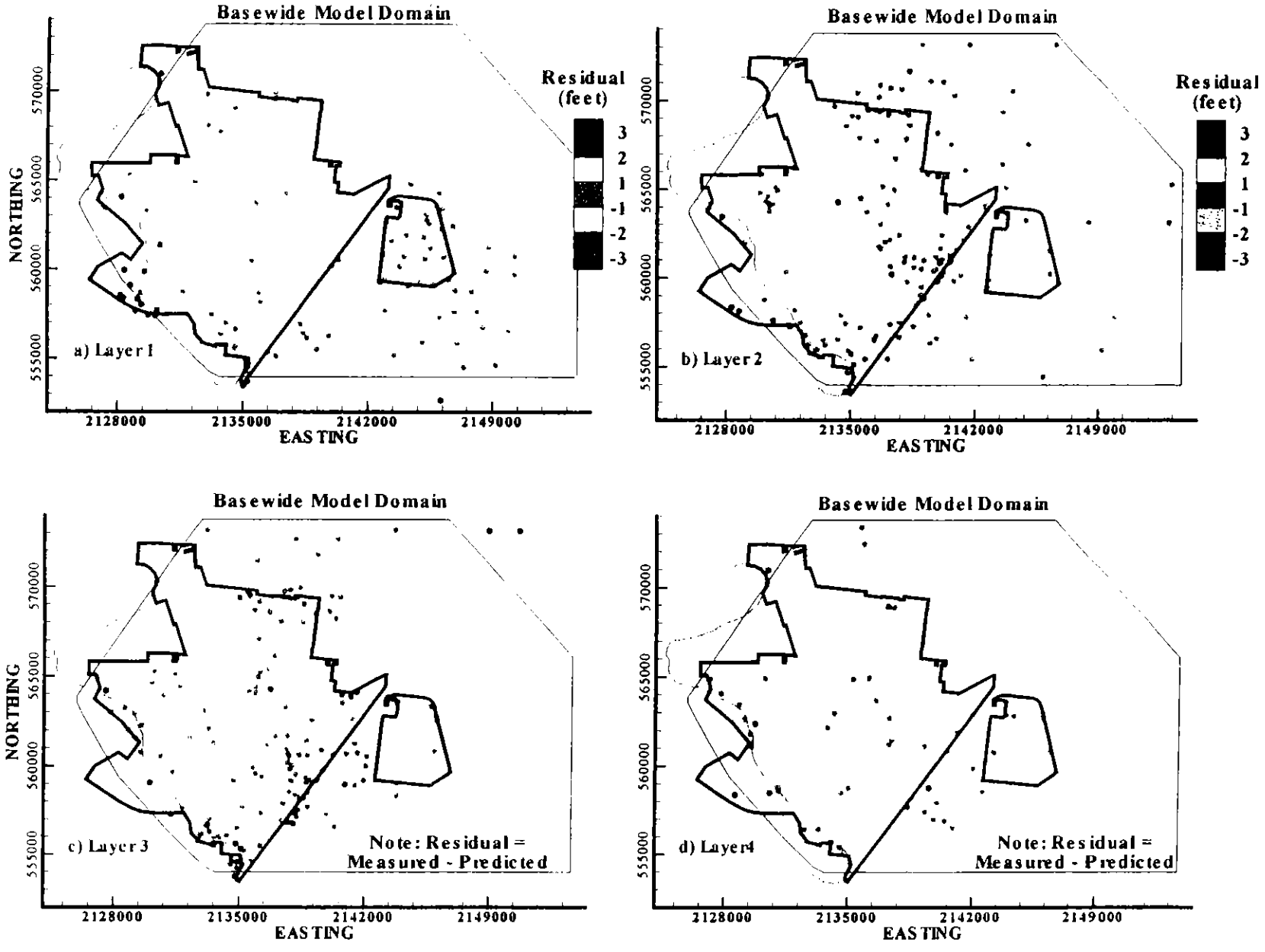


Figure 2-6 Hydraulic Heads Residual Distribution

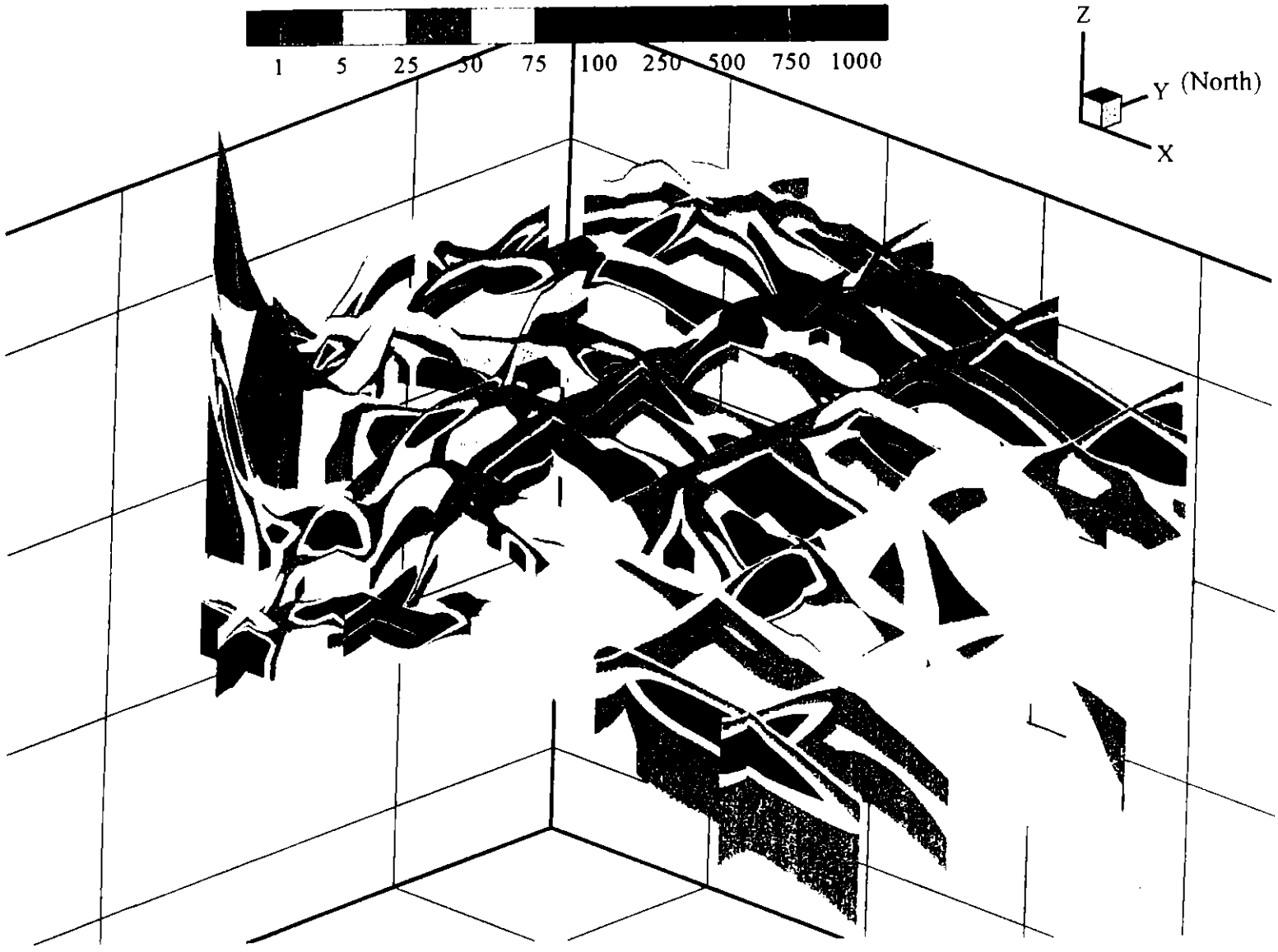


Figure 2-7 Fence Diagram of the Hydraulic Conductivity Field Produced By Model Calibration

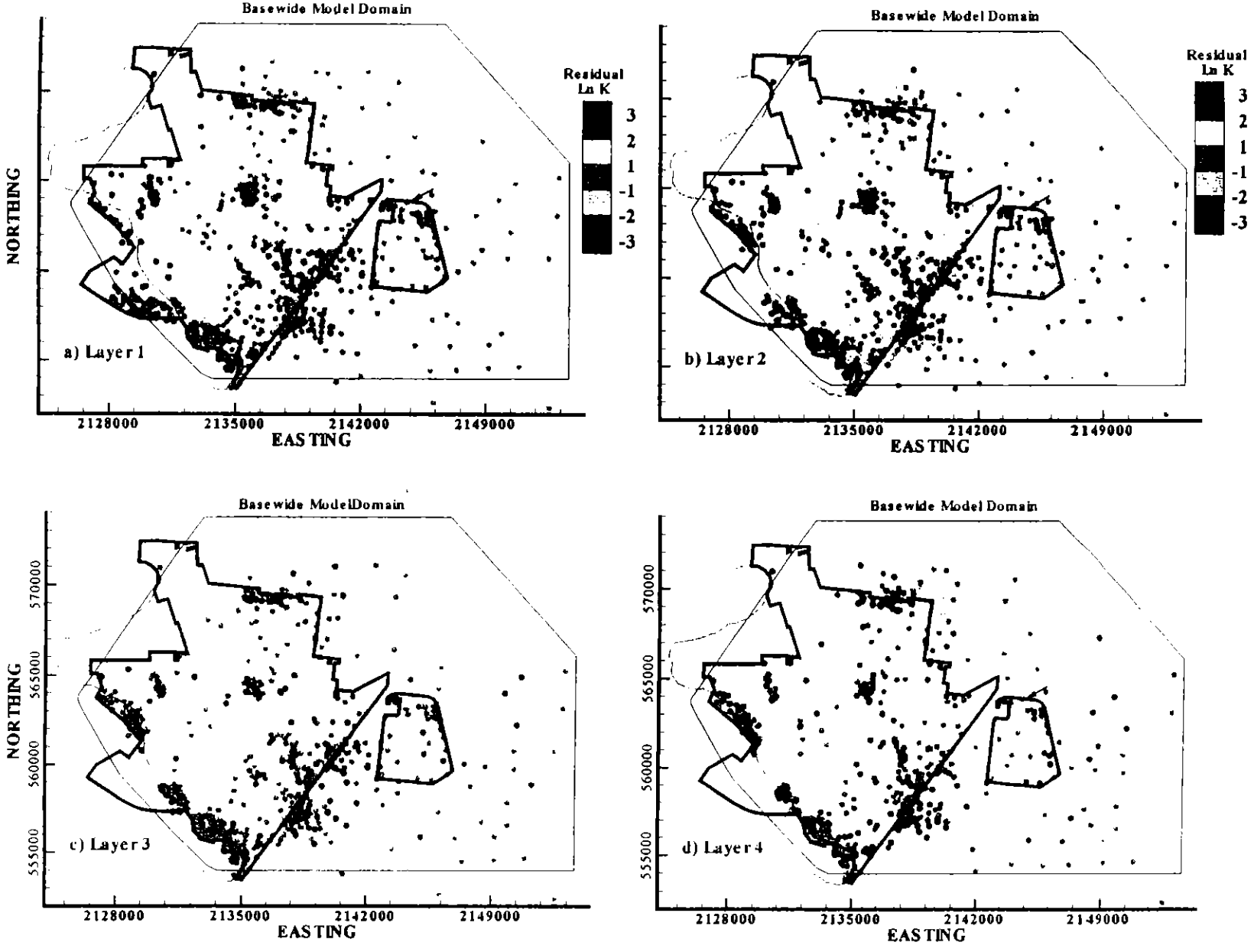


Figure 2-8 Ln (K) Residual - K Difference Between Estimated and Predicted K Values

3.0 DEVELOPMENT OF ZOOM FLOW MODEL FOR PLUME A

Two refined zoom models have been developed for several plume management areas designated as Plume A, and Plumes D, H, and J for the purpose of completion of a Corrective Measure Study (CMS) as required by the Compliance Plan (No. CP-50310) issued to Kelly AFB by the TNRCC. Section 3 documents development of a zoom model for Plume A. Section 4 describes the zoom flow model developed for Plumes D, H, and J.

As introduced in the background Section 1, contaminant transport simulations typically require a significantly finer grid discretization than does the basewide ground-water flow simulations, in order to reduce numerical dispersion of the contaminant plume front. A zoom model with a refined numerical grid can be developed within or be cut from the basewide ground-water flow model. The rationale for using a refined grid discretization in the zoom flow model is to accurately represent steep hydraulic gradients near wells and aquifer heterogonerity. The objectives of computational efficiency and the minimization of numerical error will guide the construction of a zoom model's discretization.

The hydraulic boundaries and aquifer properties of the zoom model were extracted from the portion of the basewide model that incorporates the area of interest. Hydraulic boundaries for the perimeter of the zoom model were interpolated from the boundary hydraulic head values in the basewide model. These boundary heads incorporate the effects of stresses (i.e., pumping) and features located in the basewide model but outside the zoom model boundary, and act to transfer those effects into the zoom model simulation. Hydraulic boundary conditions within the perimeter of the zoom model such as recharge at the water table, no-flow at the Navarro clay interface, pumping and injection rates at well screen locations, and drain elevations along streams are the same as those used in the basewide model. All aquifer hydrogeological properties controlling ground-water flow, such as hydraulic conductivity, were interpolated onto the elements of the zoom model from elements in the basewide ground-water flow model.

3.1 MODEL FRAMEWORK

Figure 3-1 displays the numerical grid for the zoom model for Plume A embedded within the basewide model and superimposed on a base boundary map. The Plume A model has dimensions of 13,800 feet (easting) by 8,100 feet (northing) covering an area of 4.03 square miles, or approximately one-third of the basewide model. The numerical mesh of the Plume A model has spacing of 300-ft, 100-ft, and a 50-ft, with the smallest grid space occurring at the vicinity of the proposed Plume A remediation system. The numerical grid consists of 102 rows and 109 columns of cells for a total of 11,118 grid cells in each of the 4 model layers.

The six extraction wells associated with existing Site S-1 remediation system in the basewide model domain are included in the calibration of Plume A model. Pumpage from extraction wells is represented using the fracture well package in MODFLOW-

SURFACT, which accounts for variability in flux along the well annulus caused by aquifer heterogeneities.

3.2 MODEL CALIBRATION

3.2.1 Hydraulic Head

Figure 3-2 shows the hydraulic head in all four model layers. Their contour patterns are essentially the same. In order to help evaluate the accuracy of the calibrated model, Figure 3-3 shows the differences between the measured and predicted hydraulic head values for all four model layers. For the 85 head points shown in Figure 3-3, the RMS is 0.66 feet, and the average bias is 0.34 feet, indicating that the model has a slight tendency to underpredict the hydraulic head measurement.

3.2.2 Hydraulic Conductivity

Figure 3-4 shows hydraulic conductivity (K) distributions for four model layers. The high K deposits (K>100 ft/day) mainly occur in Model Layer 3. Figure 3-5 shows the residuals (borelog estimated minus model predicted) in natural log scale for the 776 hydraulic conductivity calibration targets by model layer. The RMS for Ln K match is 1.47.

3.2.3 Flow Paths

The flow model calibration was checked to ensure that ground-water flow pathways are consistent with the movement of contaminant plumes. This check was performed by superimposing predicted flow pathlines over the outline of the contaminant plumes. This approach is good for determining if the flow pathlines have a general match to the trend of plume configurations, but because of three-dimensional flow and plume shrinkage due to biodegradation, these kinds of plots are not used for straightforward interpretation of the field data.

Flow paths are generated from the model's velocity field via particle tracking. Particle tracking involves moving particles through the three-dimensional model domain based on the ground-water velocity vectors determined for each model cell. Figure 3-6 illustrates the results of particles generated from model calibration. The particle tracks map the advective migration of ground-water with time marked in a two-year time interval. Contour intervals for the 1998 TCE concentration developed in Section 5 are overlaid on the particle tracks. To the east of the ground-water mounding area, particle movement implies radial flow with an emphasis in the east direction. In the near source area, the particles are moving with relatively low velocity (~0.2 ft/day). The particle tracking results are closely consistent with the current plume configuration in all flow directions, suggesting that the flow model is correctly calibrated, and can be used for contaminant transport simulation.

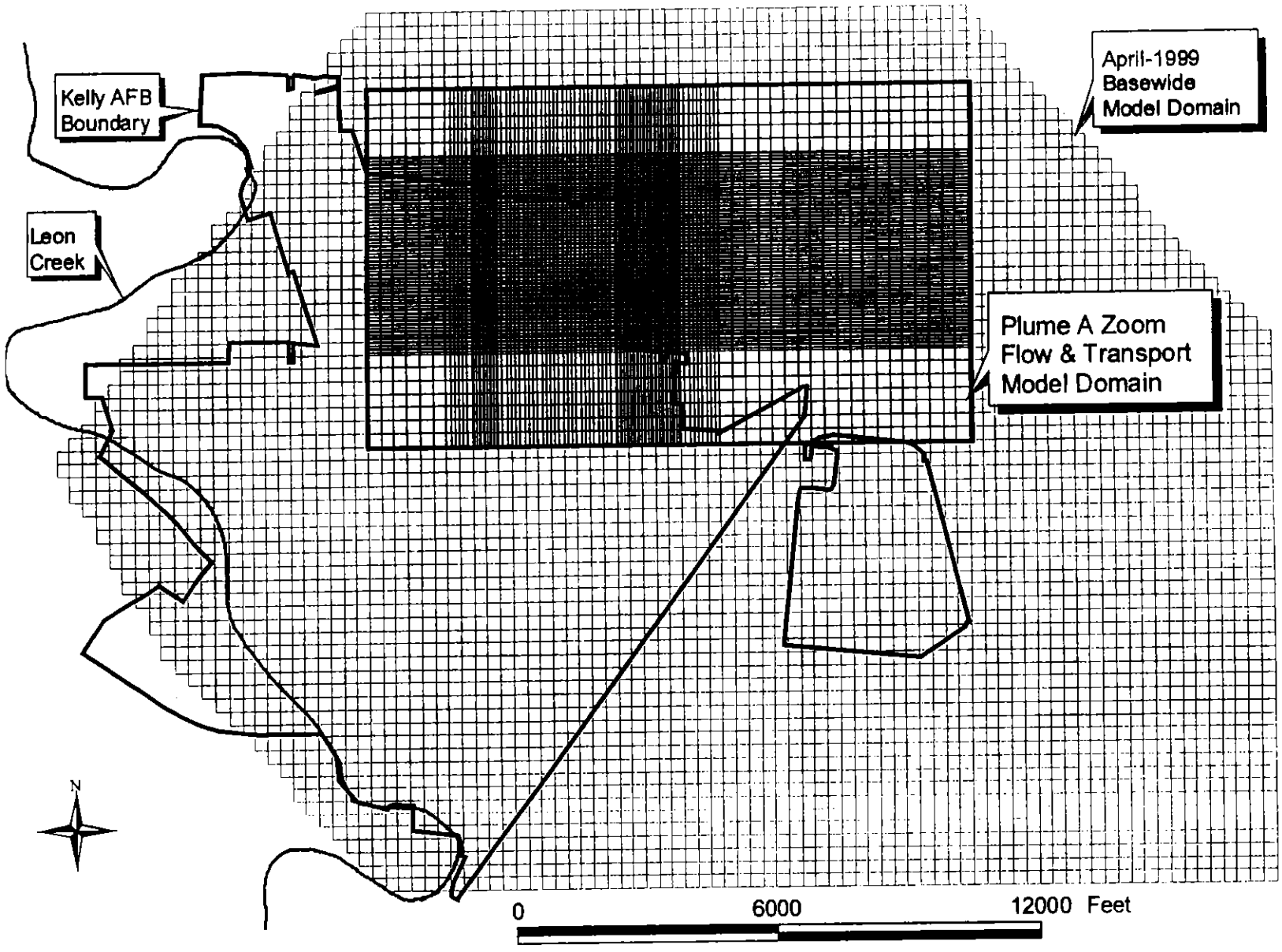


Figure 3-1 Numerical Grid of Plume A Flow and Transport Zoom Model Embedded Within the Basewide Model

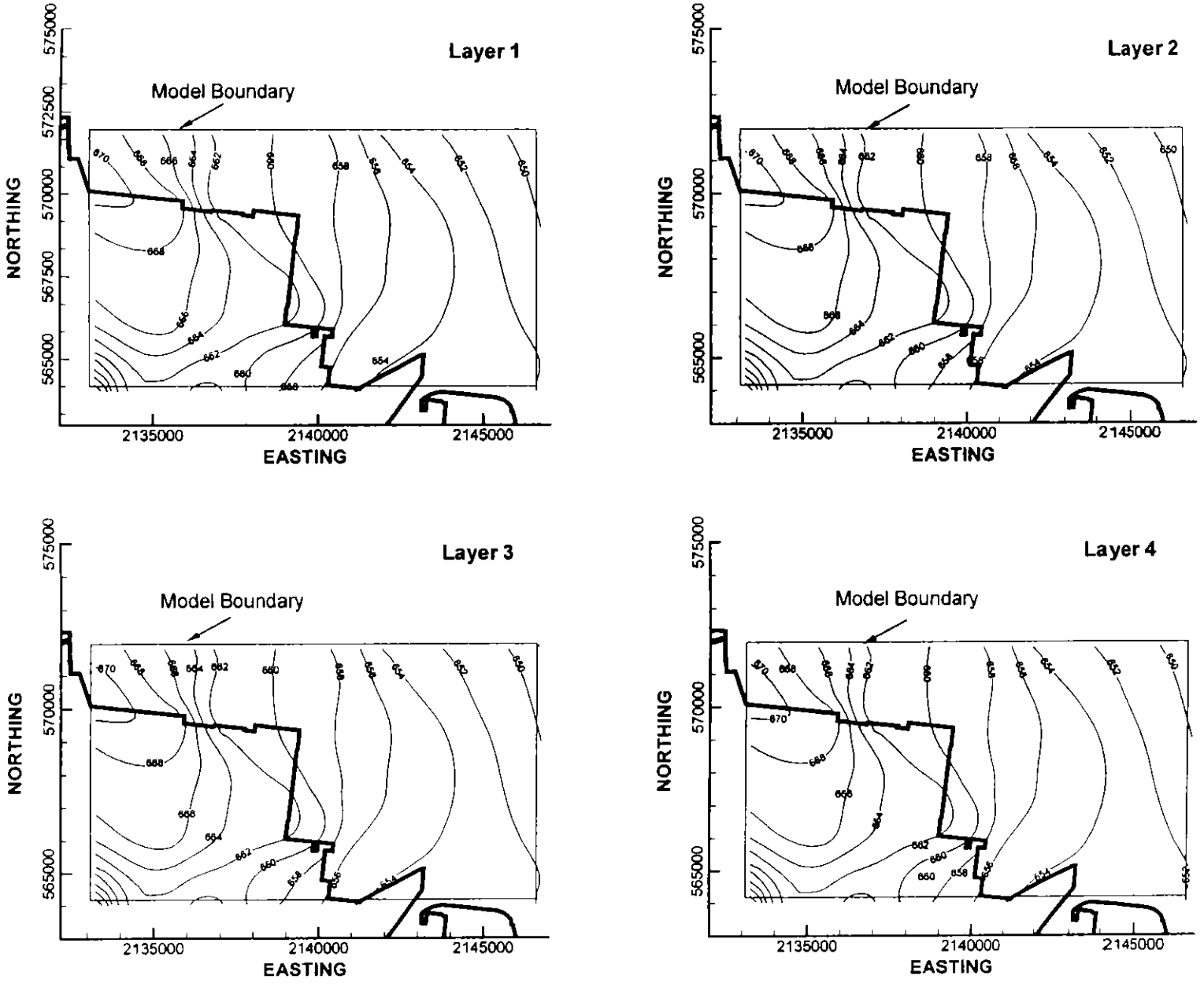


Figure 3-2 Contours of Hydraulic Heads Produced by the Plume A Flow Zoom Model Calibration

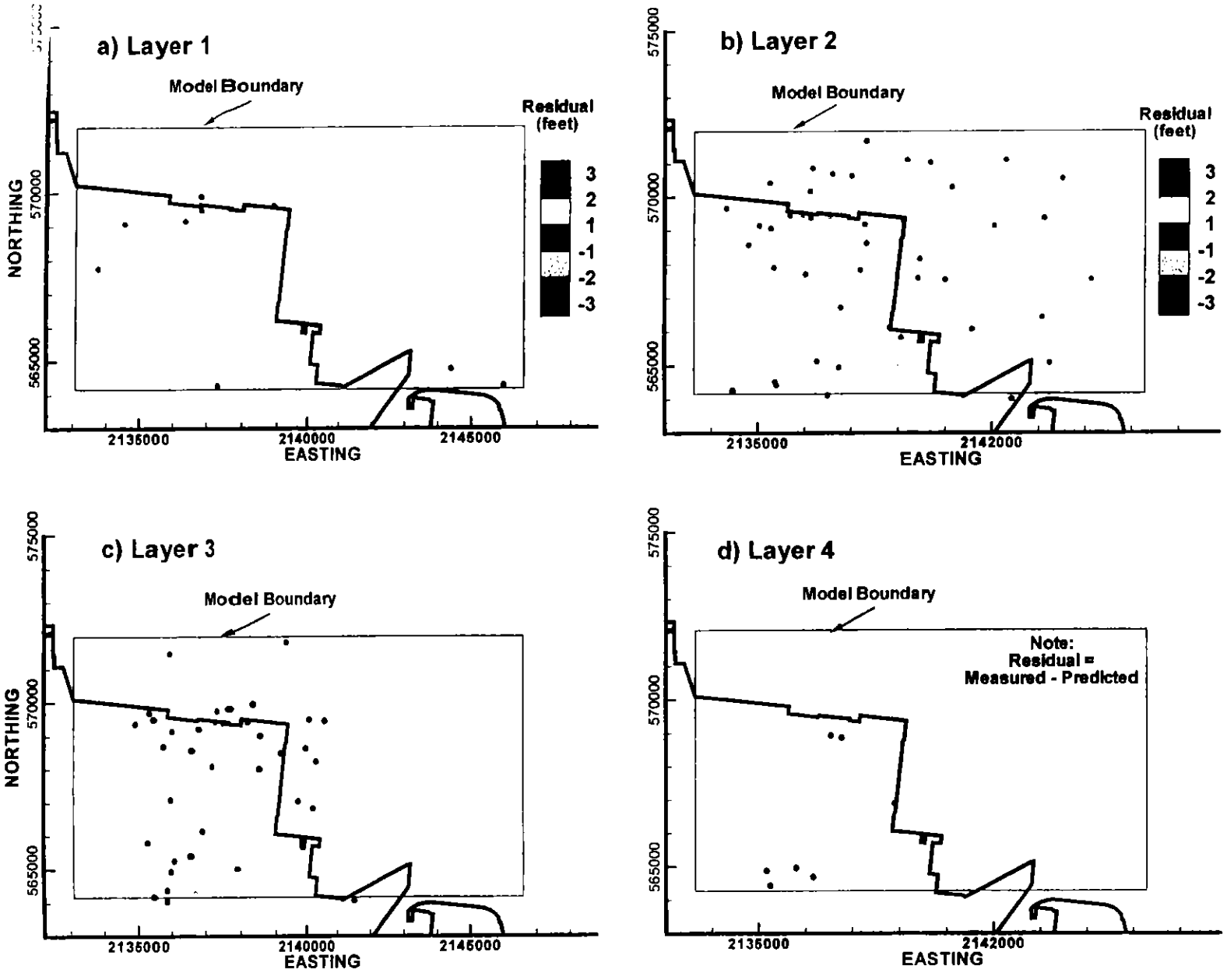


Figure 3-3 Hydraulic Head Residual Distributions

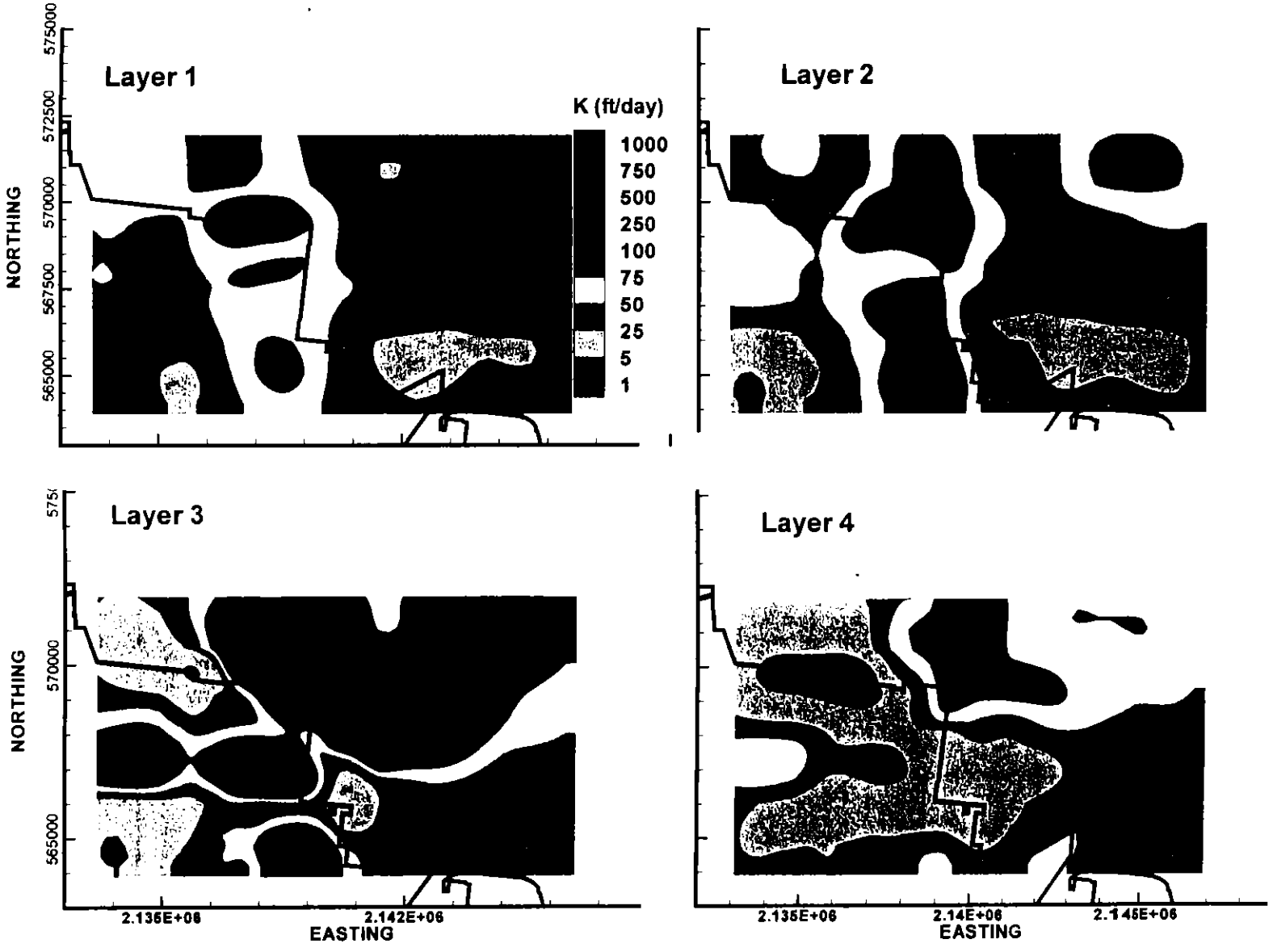


Figure 3-4 Hydraulic Conductivity Field Produced by the Plume A Flow Zoom Model Calibration

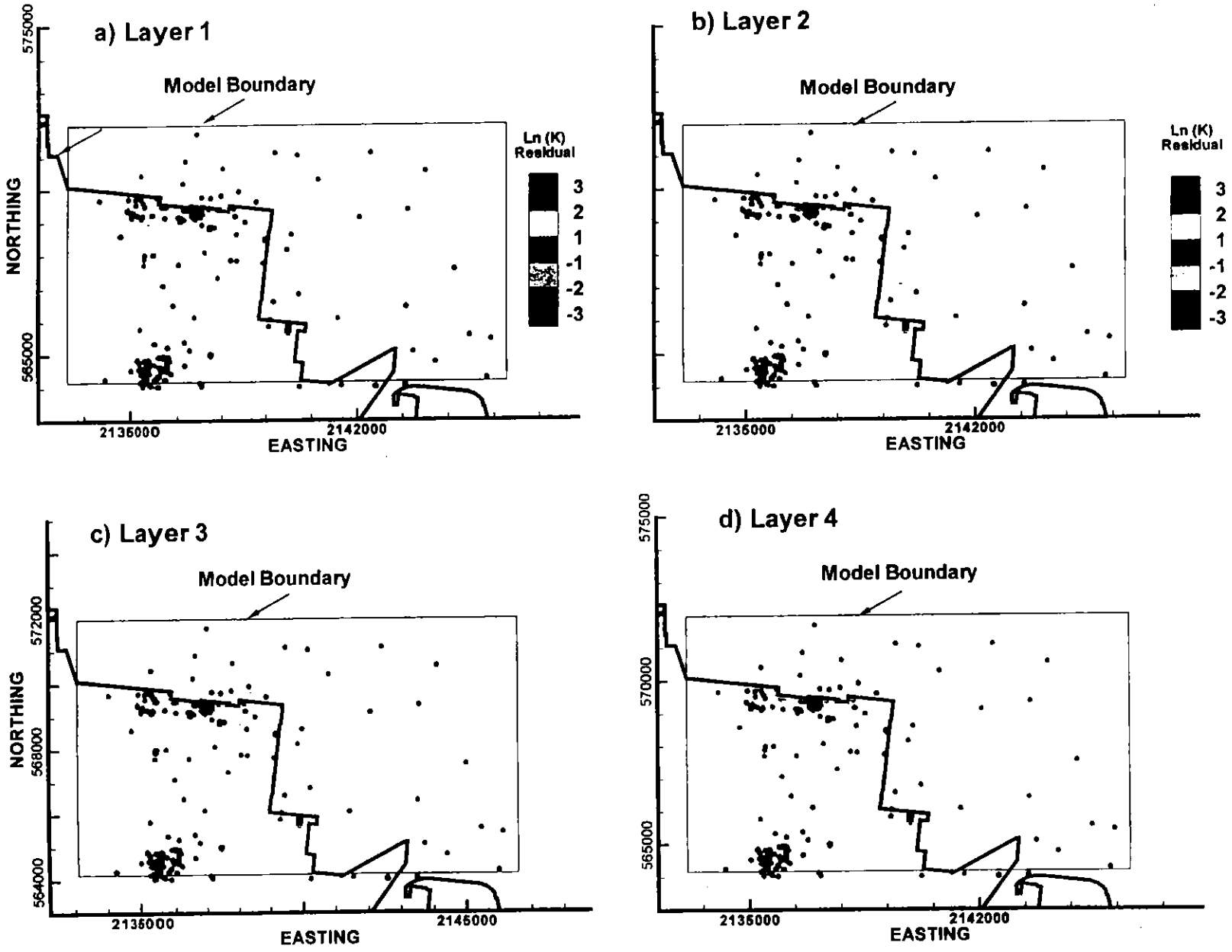
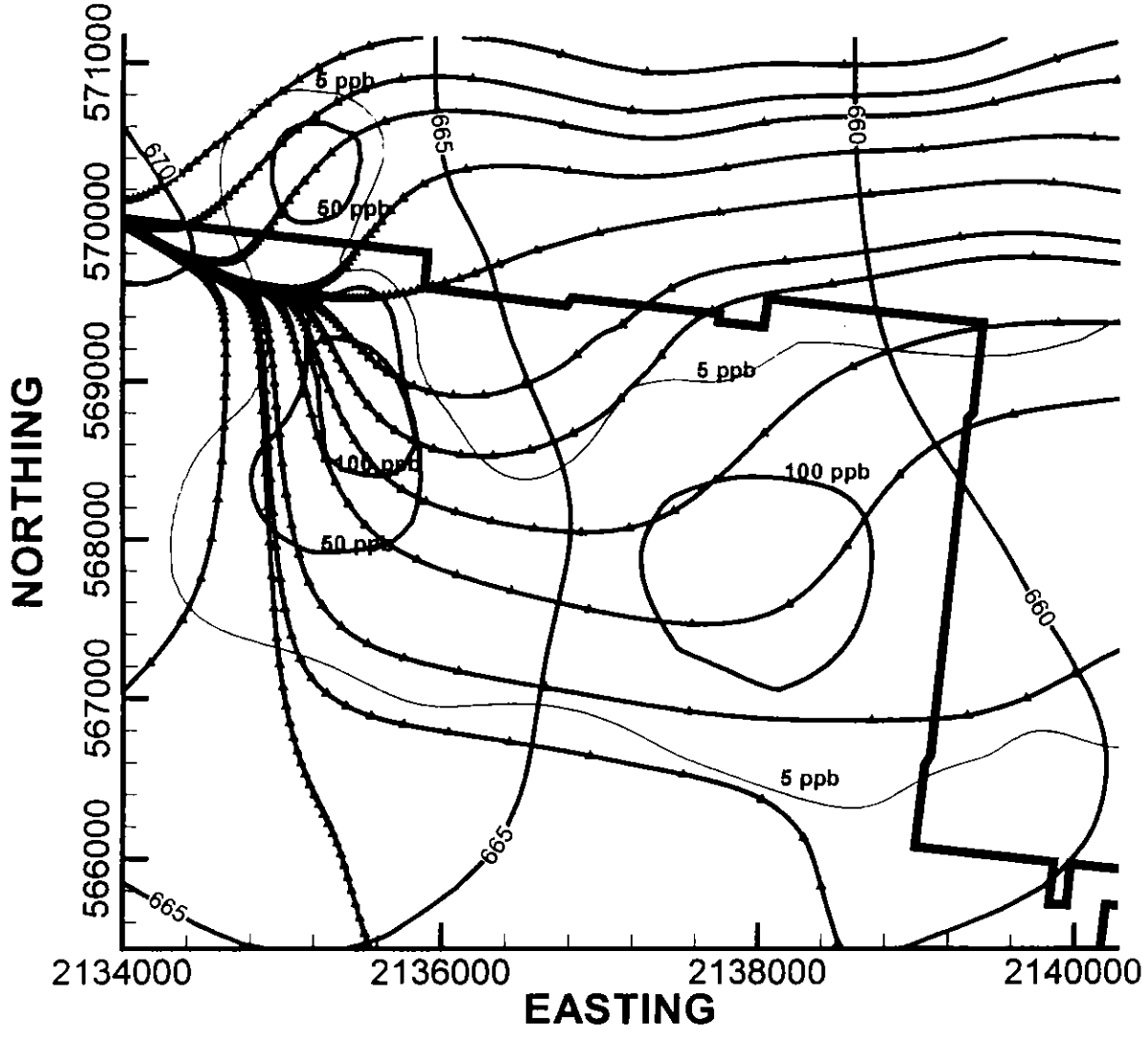


Figure 3-5 Ln (K) Residual - K Difference between Estimated and Predicted K Values



Note:
TCE plume contours are based on 1998 data. Time marker on pathlines is on 2- year interval.

Figure 3-6 Flow Pathline Generated from the Plume A Flow Zoom Model via Particle Tracking

4.0 DEVELOPMENT OF PLUMES D-H-J FLOW MODEL

4.1 MODEL FRAMEWORK

Figure 4-1 displays the Plumes D-H-J model numerical grid embedded within the basewide model and superimposed on a base boundary map. The Plumes D-H-J model has dimensions of 16,200 feet (easting) by 7,800 feet (northing) covering an area of 4.5 square miles, or approximately one-third of the basewide model. The numerical mesh of the Plumes D-H-J model has a uniform grid spacing of 300-ft and 50-ft. The refined 50 ft grid spacing is in the vicinity of the proposed Plumes D-H-J remediation systems. The numerical grid consists of 101 rows and 159 columns of cells for a total of 16,059 grid cells in each of the four model layers.

The six extraction wells associated with existing Site S-8 and MP remediation systems in the basewide model domain are included in the calibration of Plumes D-H-J model. Those wells are located in the southeast corner of the zoom model domain.

4.2 MODEL CALIBRATION

4.2.1 Hydraulic Head

Figure 4-2 shows hydraulic heads in all four model layers. The head distribution patterns for layers 2 through 4 are very similar. Figure 4-3 shows the differences between the measured and predicted hydraulic head values for all four model layers. For the 184 hydraulic head values shown in Figure 4-3, the RMS is 1.11 feet, and the average bias is 0.08 feet, indicating that the model has a slight tendency to underpredict the hydraulic head measurement.

4.2.2 Hydraulic Conductivity

Figure 4-4 shows hydraulic conductivity (K) distributions for four model layers. The low-K Navarro Escarpment near the western model boundary occurs at all four model layers, especially in Layer 4. The low-K Navarro Ridge in the central region of the model is continuous in Model Layer 4 and 3, but diminishes at the higher elevations in Model Layers 2 and 1. The high K deposits (K>100 ft/day) mainly occur in Model Layers 3 and 4. Apparently, the high K materials in the alluvial aquifer are distributed like channels on the both sides of the central Navarro Ridge. Figure 4-4 shows the residuals (borelog estimated minus model predicted) in natural log scale for the 1,834 hydraulic conductivity calibration targets by model layer. The RMS for Ln K match is 1.5.

4.2.3 Flow Paths

The flow zoom model calibration was checked to ensure that ground-water flow pathways are consistent with the movement of contaminant plumes. This check was performed by superimposing predicted flow pathlines over the outline of the contaminant plumes.

Flow paths are generated from the model's velocity field via particle tracking. Particle tracking involves moving particles through the three-dimensional model domain based on the ground-water velocity vectors determined for each model cell. Figure 4-6 illustrates the results of particles generated from zoom model calibration. The particle tracks map the advective migration of ground-water with time marked in a two-year time interval. Contour intervals for the 1998 PCE and TCE concentration developed in Section 5 are overlaid on the particle tracks. Plume H occupies a ground-water low velocity region, where it is an extension of the Navarro Ridge. The contour map of the Plume J is closely matched with the flow pathline at relatively high velocity. The highest velocity to the southeast of the model domain results from the high pumpage rates of MP and Site S-8 extraction systems.

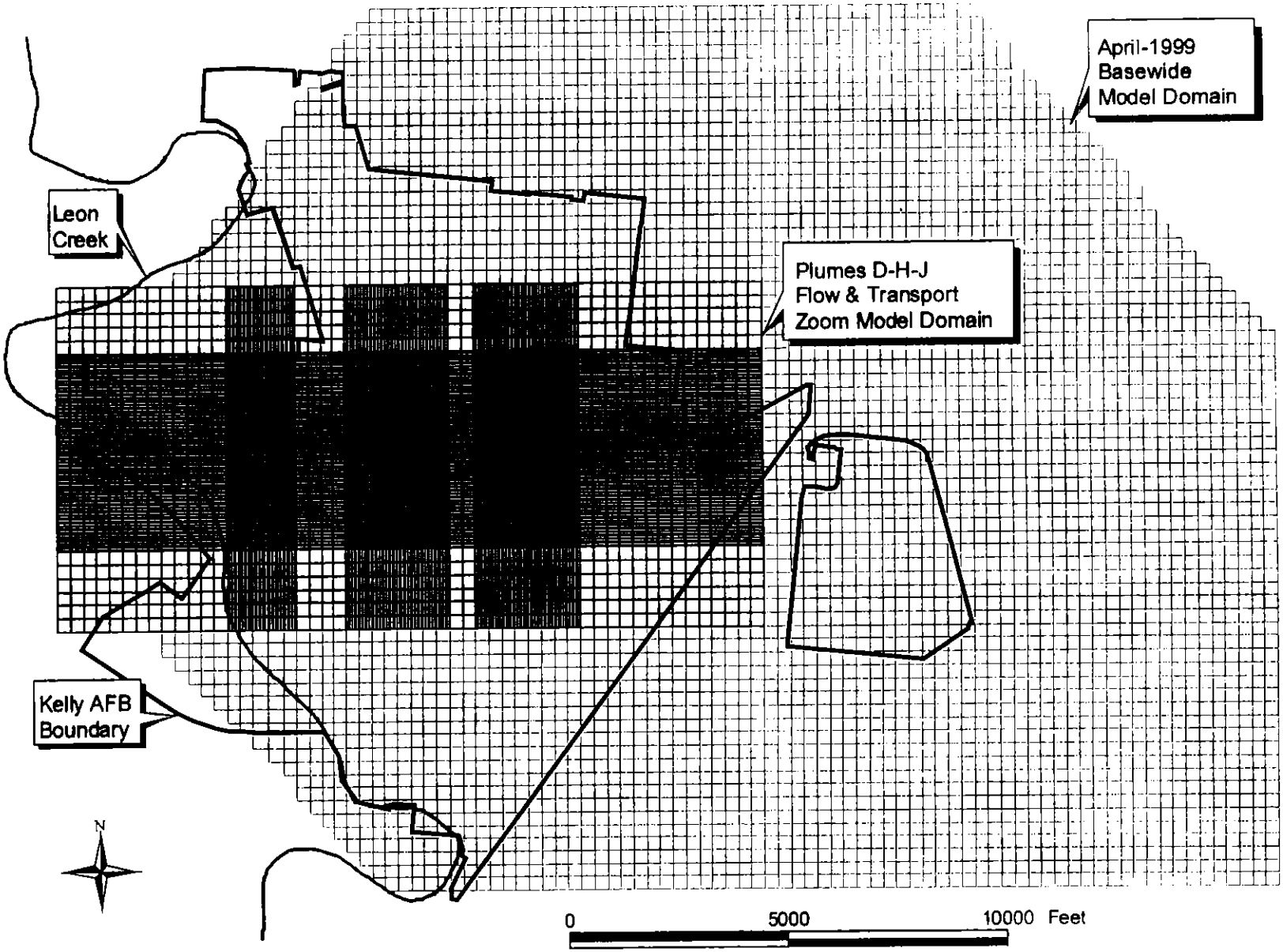


Figure 4-1 Numerical Grid of Plumes D-H-J Flow and Transport Zoom Model Embedded Within the Basewide Model

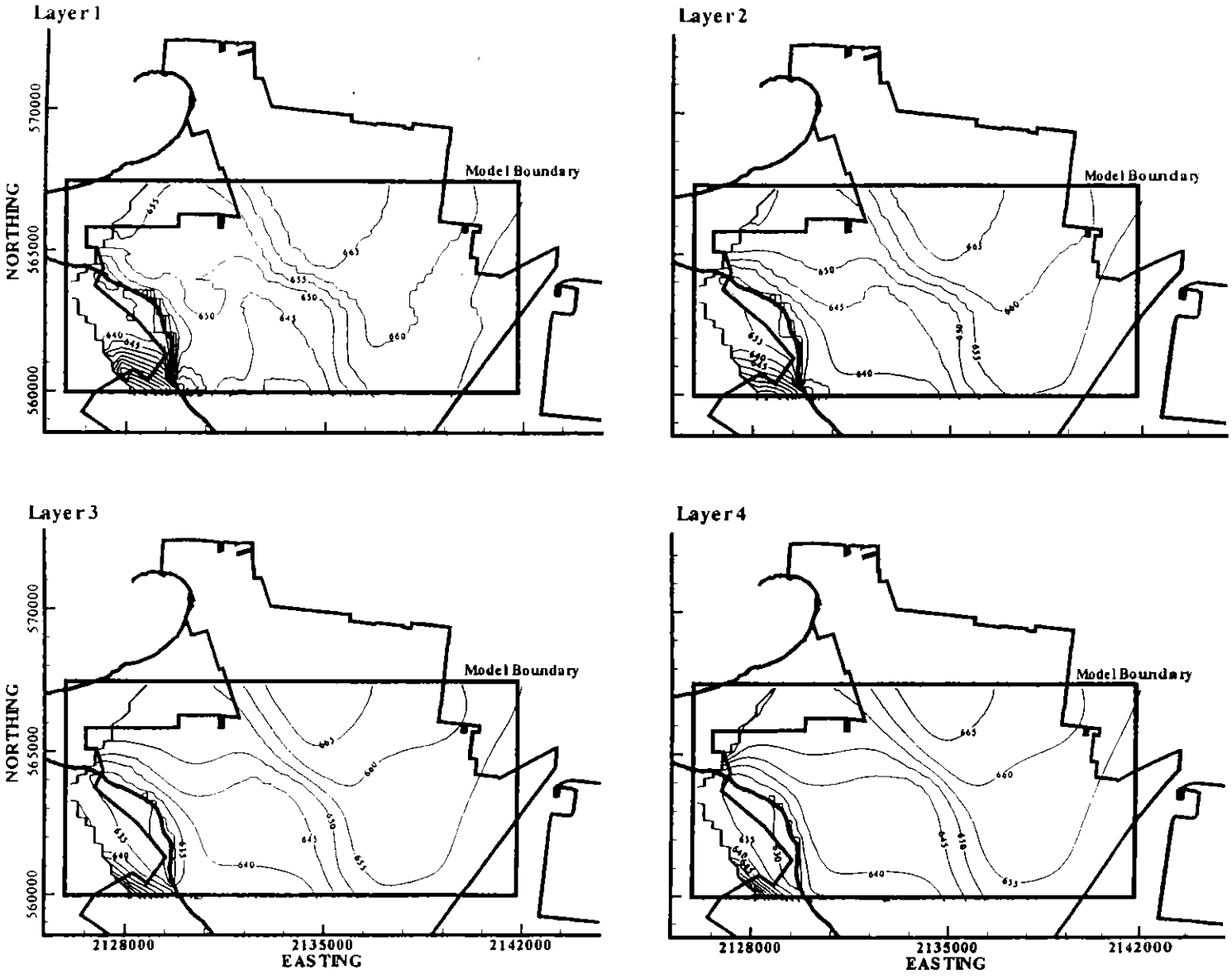


Figure 4-2 Contours of Hydraulic Heads Produced by the Plumes D-H-J Flow Zoom Model Calibration

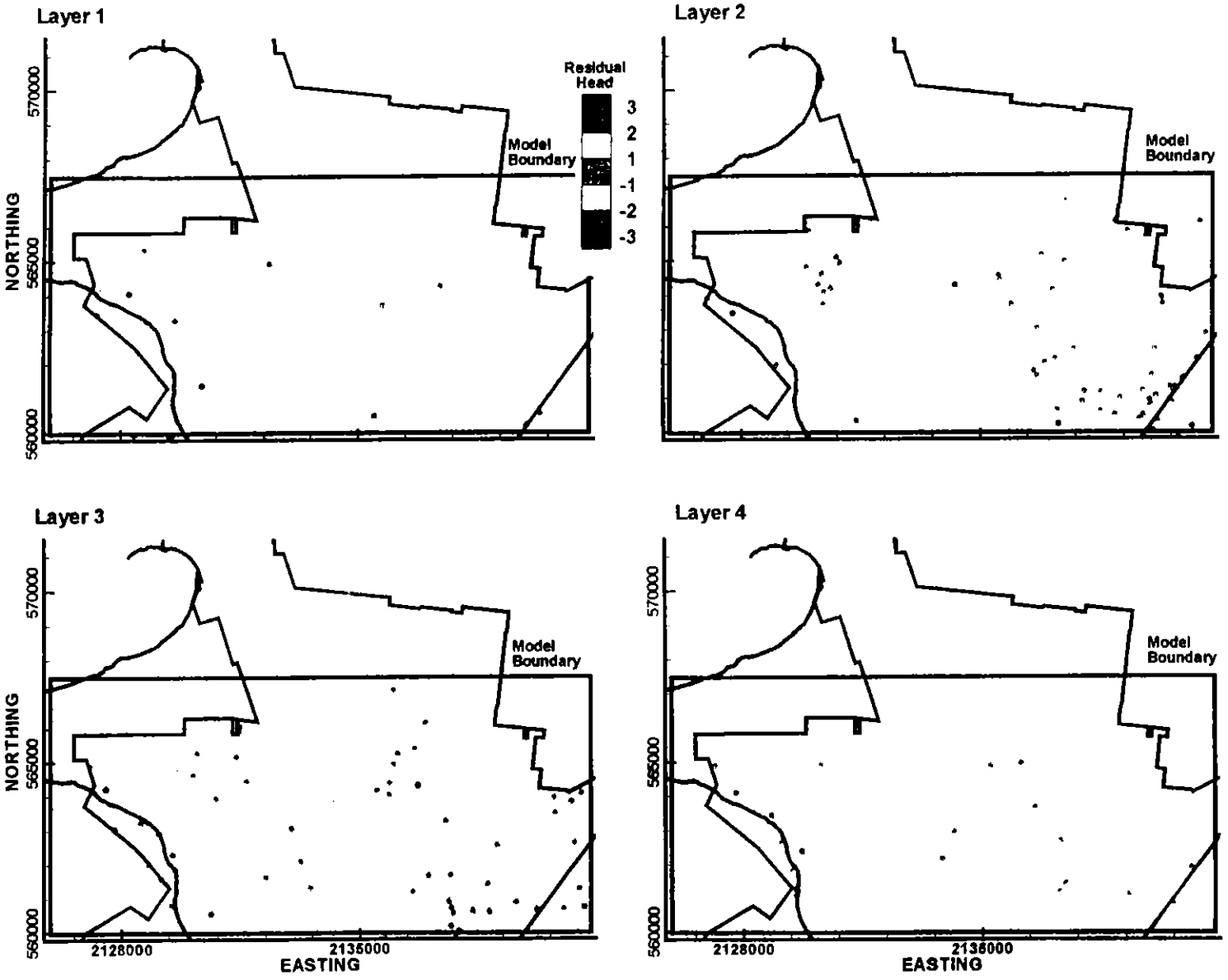


Figure 4-3 Hydraulic Head Residual Distributions

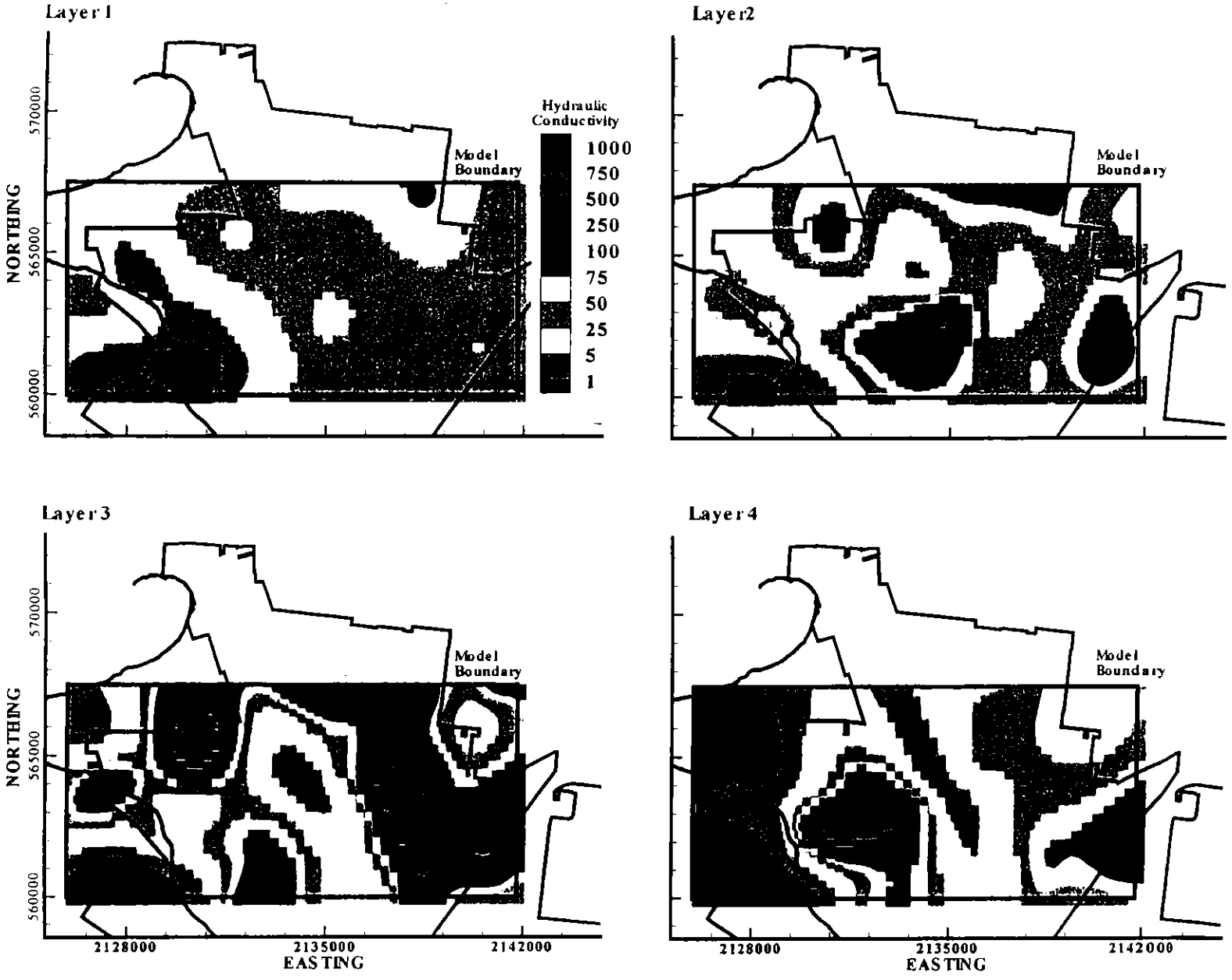


Figure 4-4 Hydraulic Conductivity Field Produced by the Plumes D-H-J Flow Zoom Model Calibration

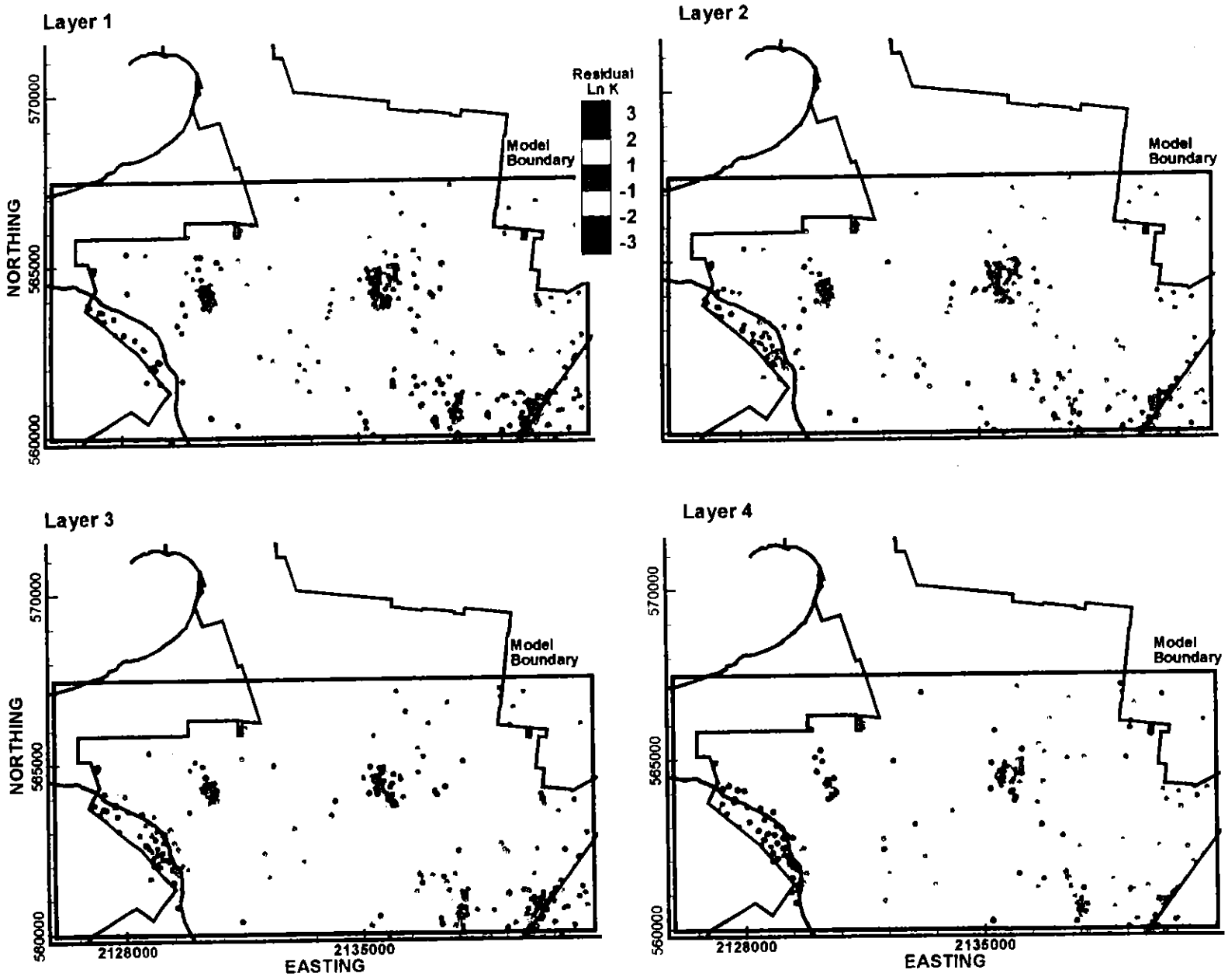
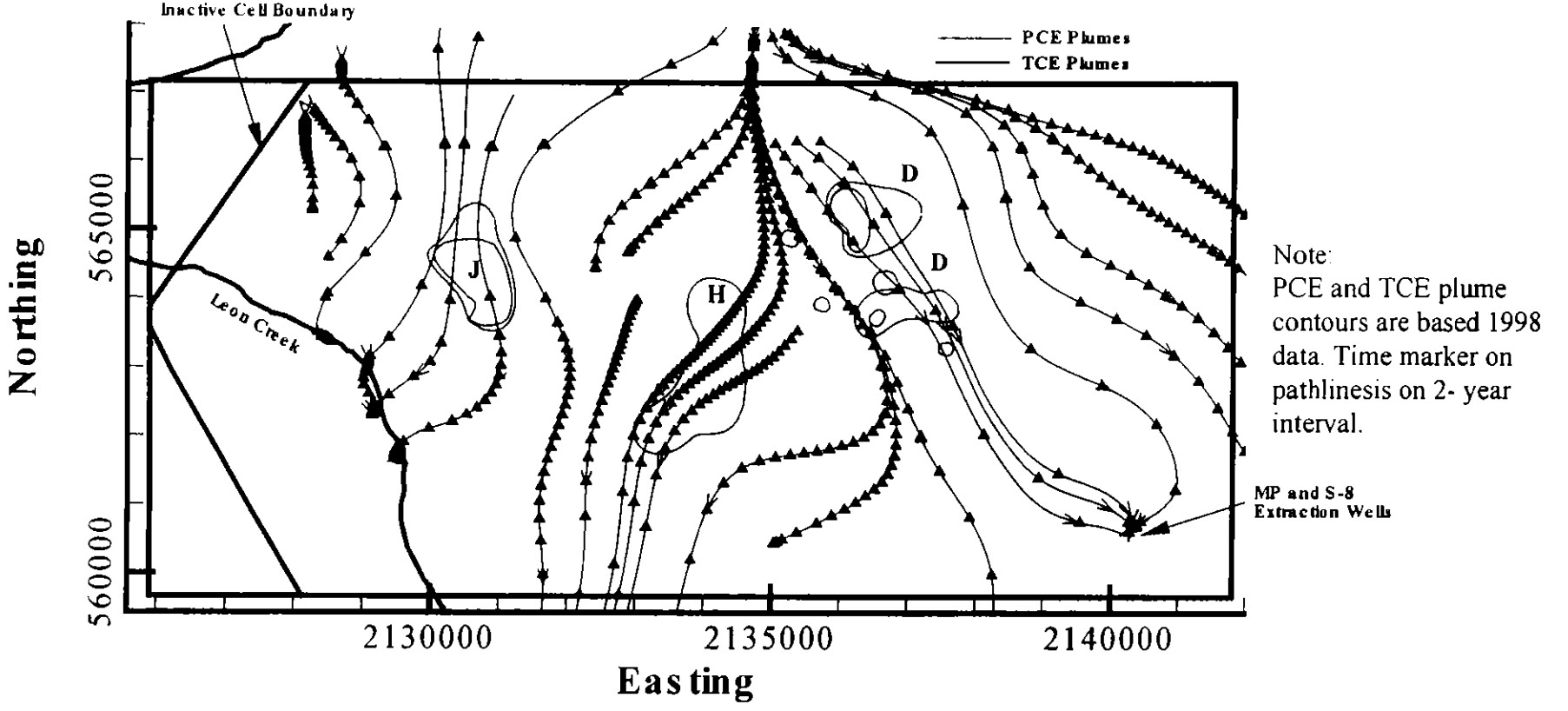


Figure 4-5 Ln (K) Residual - K Difference between Estimated and Predicted K Values



Note:
PCE and TCE plume contours are based 1998 data. Time marker on pathlinesis on 2- year interval.

Figure 4-6 Flow Pathline Generated from the Plumes D-H-J Flow Zoom Model via Particle Tracking

5.0 DEVELOPMENT OF TRANSPORT MODEL PARAMETERS

5.1 AQUIFER PROPERTIES

In order to simulate solute transport, effective porosity, dispersivity, and retardation parameters must be distributed in three-dimensions. The distribution of these values is based on a conceptual model developed from alluvial aquifer characterization data from the site.

5.1.1 Effective Porosity

Porosity is defined as the volume of voids divided by the total volume of the aquifer material, which includes both the solid portion and the void space. Effective porosity represents that portion of the void spaces that are interconnected and capable of transmitting fluid; therefore, effective porosity is used to calculate average linear ground-water velocity. For Zone 5 plume transport simulation, an effective porosity of 30% is used to represent the alluvial aquifer deposits at the site. An effective porosity of 25% was used for Site S-4 deposits in the previous Feasibility Study for Zone 3 Ground-water (HNUS, 1996), and a value of 40% was used in the draft Zone 5 RI report (CH2M Hill, 1997). For S-4 transport simulation, an effective porosity of 30% was used to represent the alluvial aquifer deposits at the site.

5.1.2 Dispersivity

Hydrodynamic dispersivity is the parameter that describes the mixing of solute in ground-water, and incorporates the effects of both molecular diffusion and mechanical dispersion. Mechanical dispersion represents mixing caused by local variations in the ground-water velocity field. Except for systems in which ground-water velocities are very low, mechanical dispersion is significantly greater than molecular diffusion. For a steady-state flow field, mechanical dispersion accounts for plume spreading in the aquifer. The lateral transverse spreading will typically be much smaller than the longitudinal transverse spreading, and in turn, the vertical transverse spreading will be much smaller than the lateral transverse spreading.

Numerous field studies have demonstrated that mechanical dispersion is controlled by aquifer heterogeneity, temporal variations in the hydraulic gradient, and the size and location of the initial plume. The conventional method for modeling dispersion is to presume a Fickian (i.e. Gaussian) dispersion process in three-dimensions similar to molecular dispersion wherein a directional-dependent dispersivity value is used instead of a molecular diffusion coefficient.

The most comprehensive compilation of field data is presented by Gelhar et al. (1992). Gelhar et al. (1992) suggest that reasonable estimates of longitudinal dispersivity are between 1 to 20 feet with the greater values associated with the most heterogeneous aquifers. Given the fluvial deposition of the Kelly aquifer an upper value of 15 ft for the longitudinal dispersivity is reasonable. Gelhar et al., (1992) report ratios of longitudinal

to lateral transverse dispersivity from about 1/5 to about 1/20. Because of the very heterogeneous nature of the deposits at Kelly AFB, a low ratio of 1/5 was used. Thus the lateral transverse dispersivity is 3 feet. Numerous field results and the theoretical results of Gelhar et al., (1992) indicate that vertical transverse dispersivity values are typically 100 times smaller than lateral transverse dispersivity and thus are on the order of molecular diffusion. For the model simulations the vertical.transverse dispersivity was set to 0.05 feet.

5.1.3 Adsorption

Adsorption of chlorinated solvents onto soils is based on retardation factors (R_f), which represents the ratio between the total solute mass (including both adsorbed and dissolved) to the solute mass dissolved in ground-water. The following equation for calculating retardation factors, R_f, has previously been used at Kelly AFB and many other CERCLA/RCRA sites:

$$R_f = 1 + (\rho/n) * (f_{oc} * K_{ow})$$

Where:
- ρ = bulk density
- n = porosity
- f_{oc} = fraction of organic carbon
- K_{ow} = octanol/water partition coefficient

Among the implicit assumptions with retardation factors is that adsorption is directly proportional to the amount of organic carbon in the soil. Estimates of soil f_{oc} values are typically based on the total organic carbon (TOC) measured in the soil. The f_{oc} values used in the Kelly AFB reports from HNUS (1996), Parsons (1998), and CH2M Hill (1999) have been approximately 0.05%, or 500 milligram per kilogram (mg/Kg).

Table 5-1 summarizes the retardation factors calculated for four chlorinated solvents of interest at Zone 5. The calculations are based on a porosity of 0.3, a bulk density of 1.7 grams per cubic centimeter (gm/cm^3), a fraction of organic carbon of 0.05, and an octanol/water partition coefficient extracted from the literature citation. The retardation factors range from 2.0 to 1.0. The higher the retardation factor the greater the adsorption and thus the greater the solute movement is retarded as compared to the ground-water migration. The magnitude of the retardation factor is the factor by which the average solute velocity is slower than the average ground-water velocity. Thus, with a retardation factor of 2.0, PCE moves at half the velocity of ground-water.

Table 5-1
Calculated Retardation Factors for PCE, TCE, DCE, and VC

Chlorinated Compound	Retardation Factor	K_{ow}	
		Value	Reference
PCE	2.0	364	Pankow and Cherry, 1996
TCE	1.4	126	Pankow and Cherry, 1996
DCE *	1.2	86	Pankow and Cherry, 1996
VC	1.0	2.5	Montgomery and Welkom, 1990

Notes: Koc is dependent on the DCE isomer. The reported value is for cis-1,2 DCE.

5.2 BIODEGRADATION OF CHLORINATED SOLVENTS

5.2.1 Overview of Plume Data

CH2M Hill provided HydroGeoLogic with solvent concentration contours for all Zone 5 plumes. The solvent contours are based on a composite data set from 1996-1997 RI/BRA reports. There is no contour mapped for VC, and the TCE contour is not closed to the east off-base. HydroGeoLogic obtained a download of all solvent concentrations from 1990 to 1998 from ERPMIS database. The query results based on sampling year for this historical database indicated that more than one-third of chemical data collection was conducted in 1998. Also, the 1998 data set has the largest geographical coverage. Therefore, data evaluation for solvent concentrations was primary based on 1998 data set. Figures 5-1a, b, c show TCE, DCE, and VC concentration data points equal to or greater than their respective MCLs for Plume A. Figures 5-2a, b present PCE, TCE, DCE, and VC concentration points equal to or greater than their respective MCLs for Plumes D-H-J. Figures 5-1a b, c, and 5-2a, b also show contours generated from the 1998 data set, which are slightly different from those of CH2M Hill contours due to different data sets and interpolation. The 1998 data points and contours were used to develop an initial plume concentration file for transport simulations.

Insufficient geochemical parameter data is available in the above Zone 5 plume areas to characterize the geochemical regime as aerobic, anaerobic, or strongly anaerobic. From these limited data, it appears that there is natural biodegradation occurring, but it is not as intensive as in the Site S-4 area, where there is abundant carbon organic supply.

5.2.2 Biodegradation Rates Based on Break-Through Curve Analysis

For all transport simulation, the biodegradation rates of PCE, TCE, DCE, and VC will be assumed to follow first-order reactions. The rate constants can be determined based on concentration break-through curve analysis. Break-through curves were constructed using either the change in concentration over time or the change in concentration over distance. The construction of break-through curves requires information about the rate and direction of the plume migration from monitoring well locations along the same ground-water flow path. The direction of plume movement can be inferred from the spatial trends in the water level measurements at the monitoring well locations. The rate

of plume movement can be obtained from a large-scale, natural-gradient tracer test or from a calibrated ground-water flow model.

A visual inspection of particle tracks and concentration plots indicated that only one set of break-through curves can be generated from the available data. The most promising concentration data consists of the monitoring wells with triangle in Figure 5-1a, b. The travel time and velocity estimated for those data point from the particle tracks were used to construct break-through curves for TCE and DCE concentrations so that biodegradation rates could be calculated using the one-dimensional analytical solution of Buscheck and Alcantar (1995).

Buscheck and Alcantar (1995) have derived a method for calculating first-order decay rate constants using the equation shown below. The method involves coupling a regression of contaminant concentration (plotted on a logarithmic scale) versus distance downgradient (plotted on a linear scale) to an analytical solution for one-dimensional, steady-state, contaminant transport that includes advection, dispersion, sorption, and biodegradation.

$$\lambda = \frac{v_c}{4\alpha_x}\left[\left(1 + 2\alpha_x \frac{K}{v_x}\right)^2 - 1\right]$$

where:

λ = first-order rate constant
v_c = retarded contaminant velocity in the x direction
α_x = longitudinal dispersivity
K/v_x = slope of line formed by making a log linear plot of contaminant concentration versus distance downgradient along the flow path

Presented in Figure 5-3 are semilog plots required to support the analytical solution (Buscheck and Alcantar, 1995) for calculating biodegradation rates for TCE and DCE at Plume A area. For both TCE and DCE, a linear regression was performed on the concentration data from monitoring wells highlighted in Figures 5-1. These four monitoring wells are located most closely following the particle tracks from the Plume A TCE source-area to downgradient in Figure 3-6. Using the slope of these lines, velocity based on the zoom flow model, and a longitudinal dispersivity of 15 feet, the Buscheck-Alcantar equation calculates biodegradation rates with half-lives of 5.9 and 4.0 years for TCE and DCE, respectively.

5.2.3 Summary of Biodegradation Rate Constants

In order to help evaluate the reasonableness of the biodegradation half-lives calculated in Section 5.2.2, Table 5-2 summarizes the half-lives calculated for Site S-4 at Kelly AFB. At Site S-4, a detailed analysis was performed on an extensive site of geochemical and solvent concentration data by HydroGeoLogic (1999b). Based on a joint analysis of break-through curves and numerical modeling results, the first-order biodegradation half-

lives selected for the anaerobic regions of Site S-4 are 4 years, 4 years, 3 years, and 2 years, for PCE, TCE, DCE, and VC, respectively (HydroGeoLogic, 1999b). For the transitional and aerobic regions of Site S-4 the model simulations suggested that: the half-lives for PCE and TCE are about 5 to 6 years, the half-lives for DCE and VC is about 4 and 1 years, respectively.

Based on the limited geochemical information, the absence of any man-made carbon-source plumes, the small VC plume, and the relatively high values for the calculated half-lives for TCE in Zone 5, Zone 5 is presumed to have plumes with redox potentials characterized by transitional to aerobic conditions. For this condition, the assumptions of half-lives of 8 year for PCE and 1 year for VC are reasonable. Combining these half-lives with those determined for TCE and DCE in the previous section provide the half-lives for all solvents for Zone 5 as shown in Table 5-2.

Table 5-2
Summary of Biodegradation Half-Lives (yr) Used for Transport Simulation at Site S-4 and Zone 5 Plumes for PCE, TCE, DCE, and VC

	Site S-4			Zone 5 Plumes
	Numerical Modeling Results	Breakthrough Curve Analysis		
		Method of Buscheck & Alcantar	Visual Inspection of Linearly Plotted Values	
PCE	~2	2.3 - 3.0	2-4	8
TCE	~2	2.4 - 3.0	2-4	6
DCE	~3	NVC	3	4
VC	~~0.75 to <2.5	NVC	2	1

note: NVC = No Values Calculated

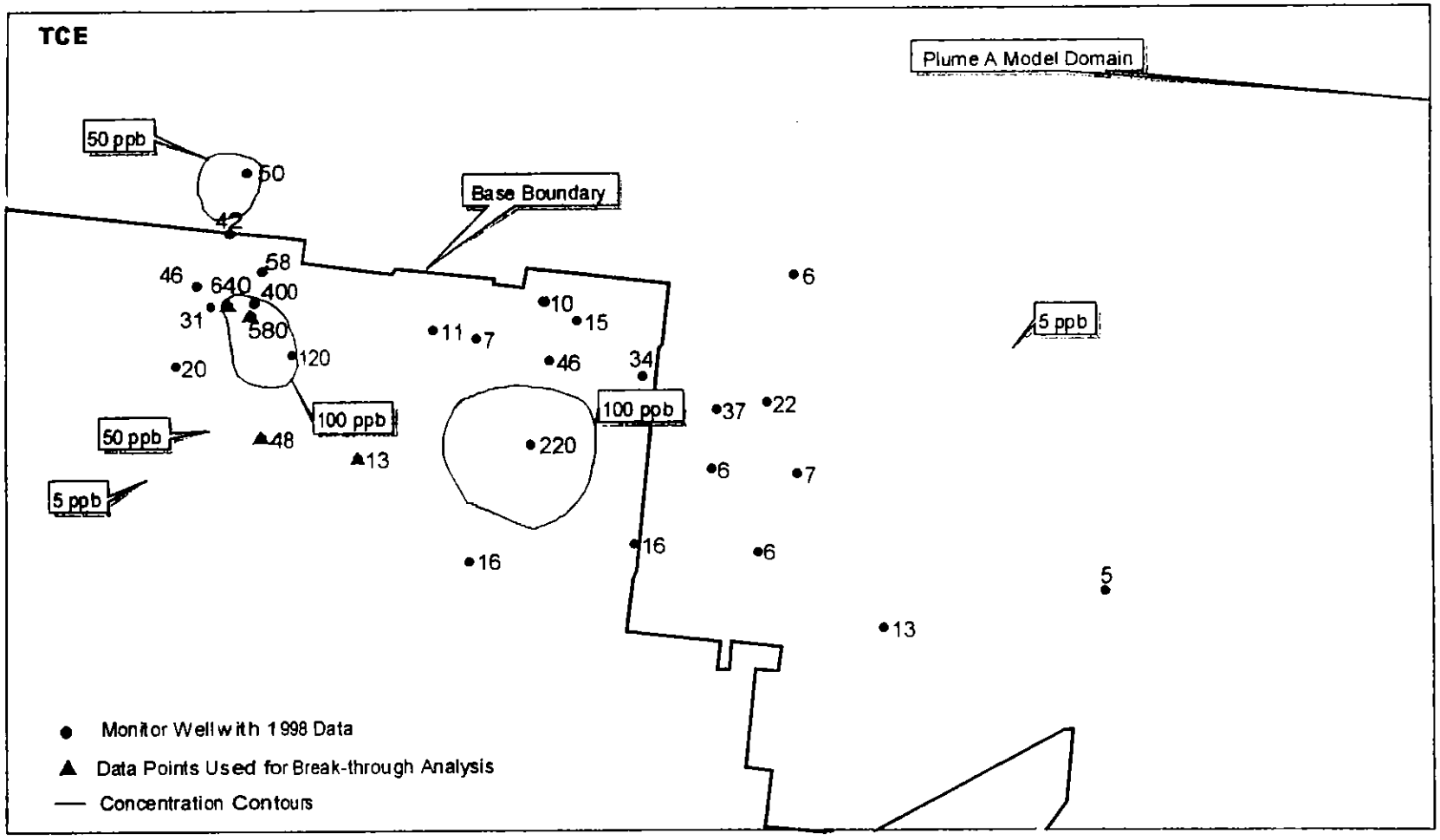


Figure 5-1a TCE Concentration and Contour for Plume A.

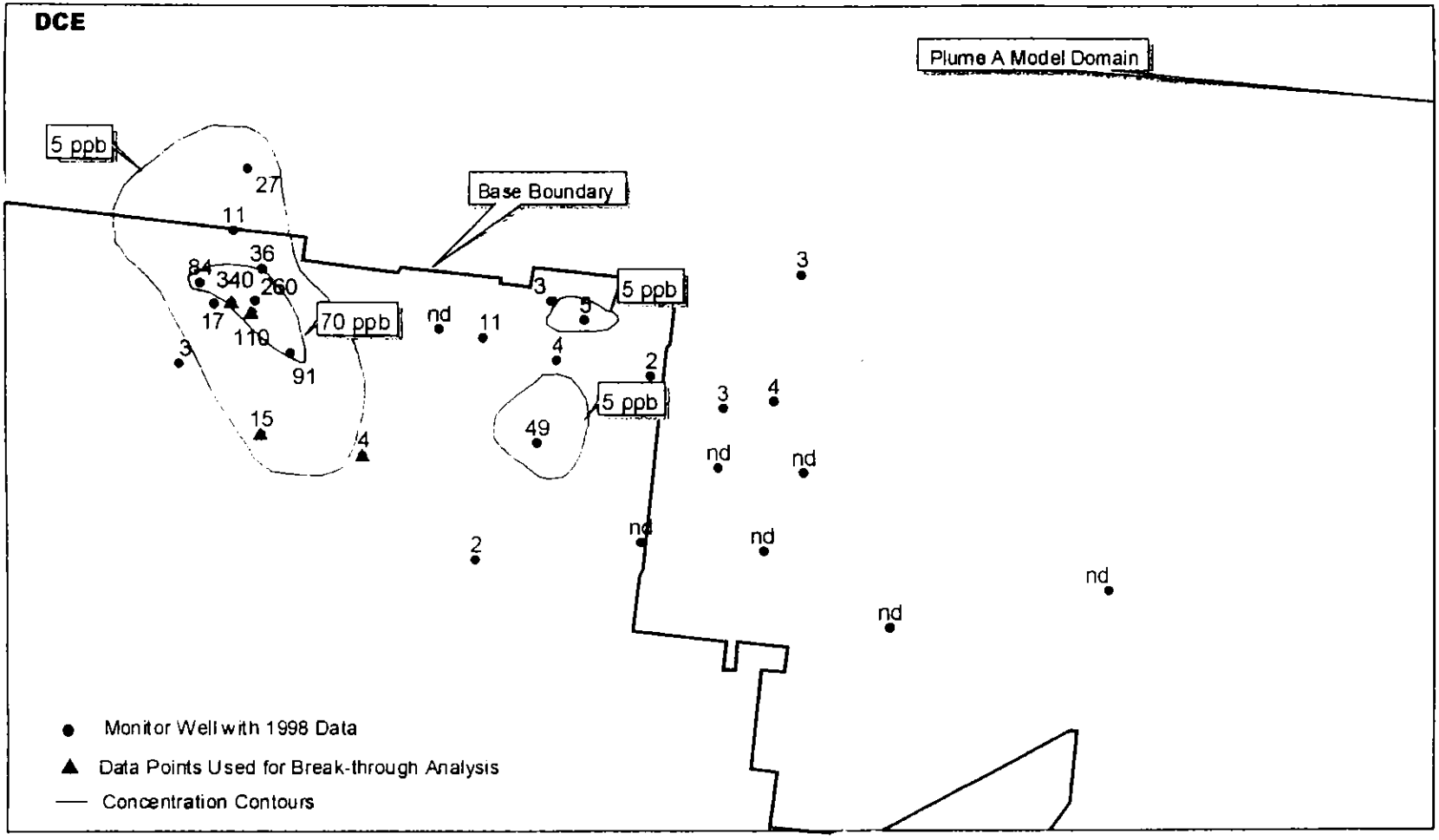


Figure 5-1b DCE Concentration and Contour for Plume A

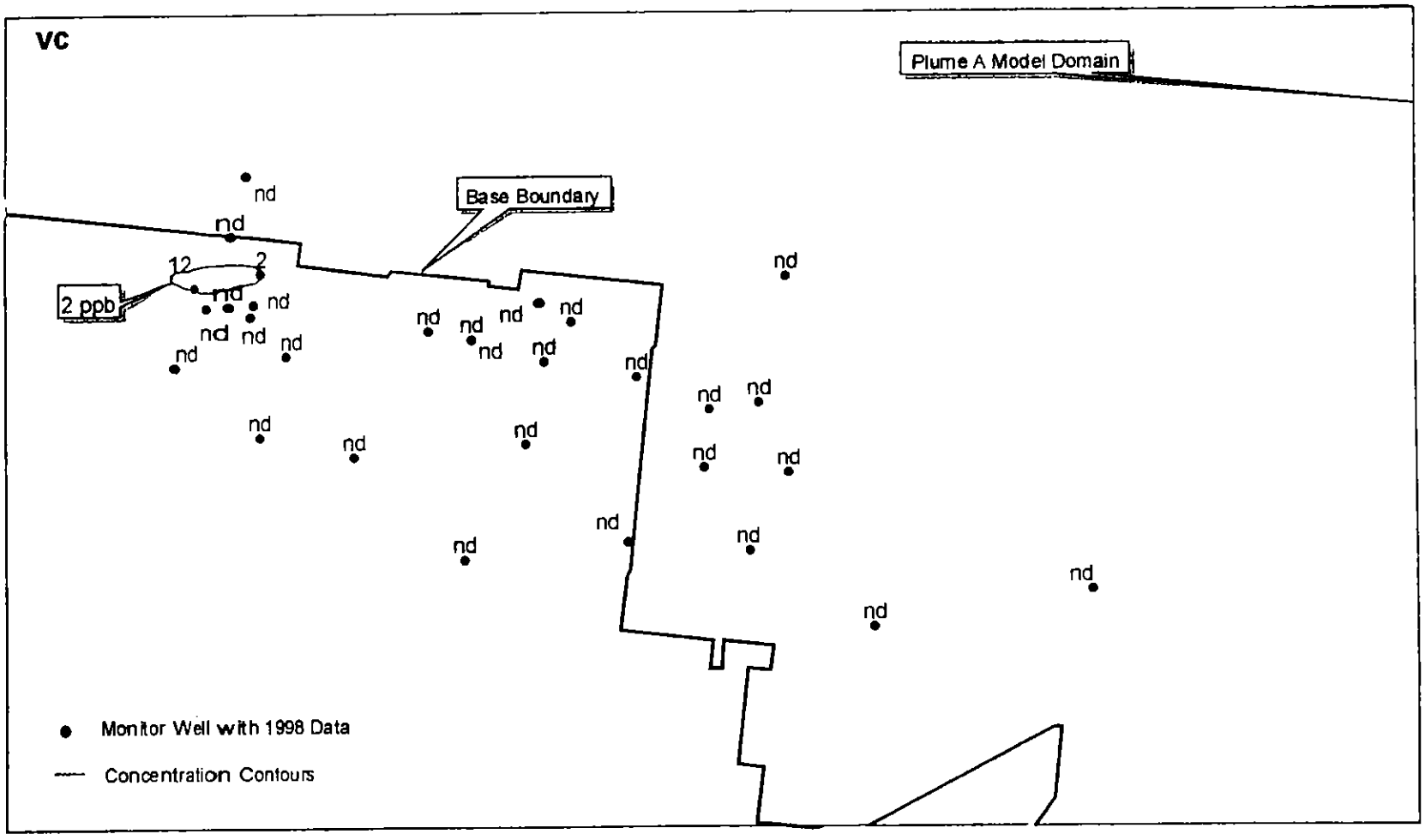


Figure 5-1c VC Concentration and Contour for Plume A.

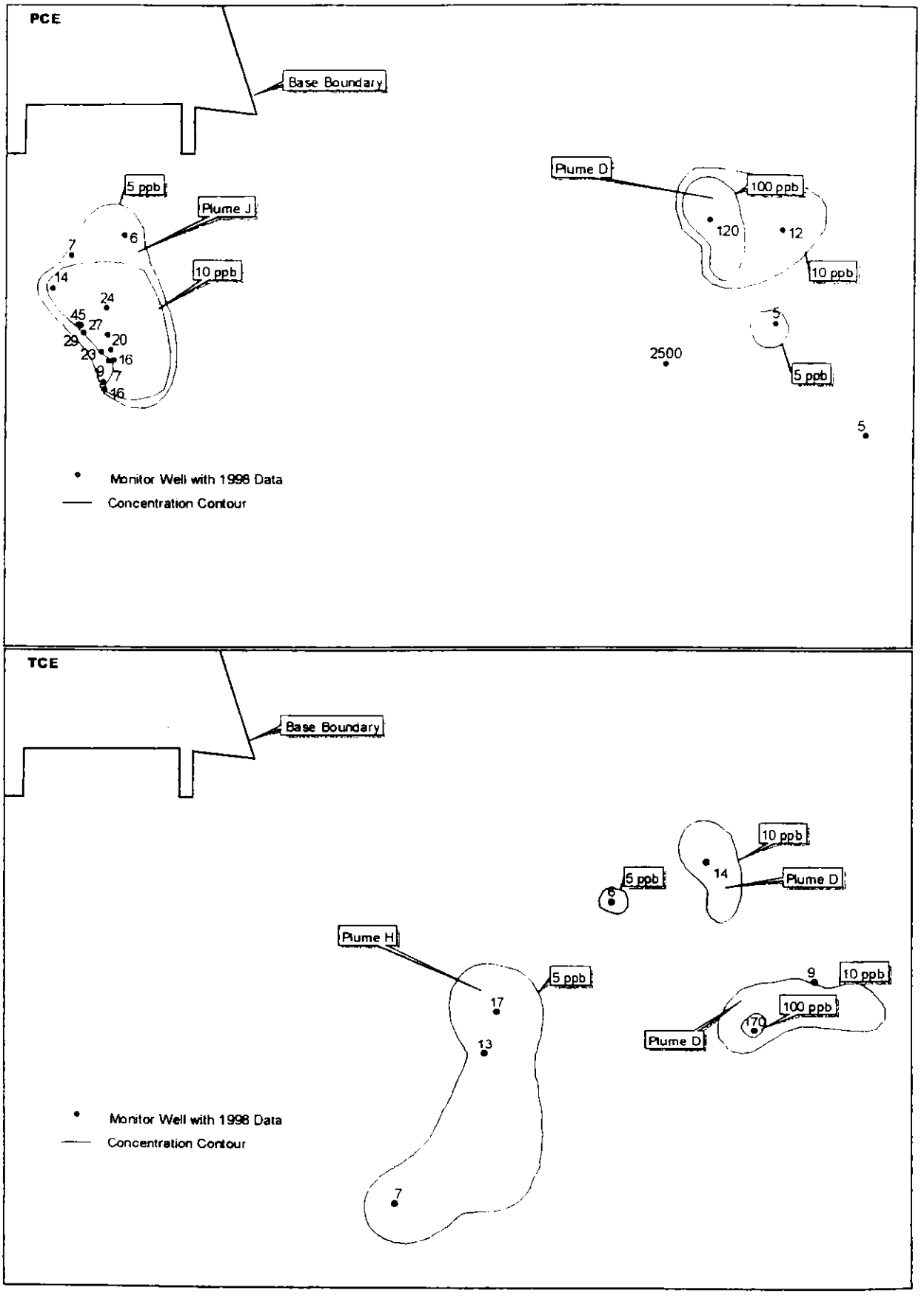


Figure 5-2a PCE and TCE Concentrations and Contours for Plumes D-H-J

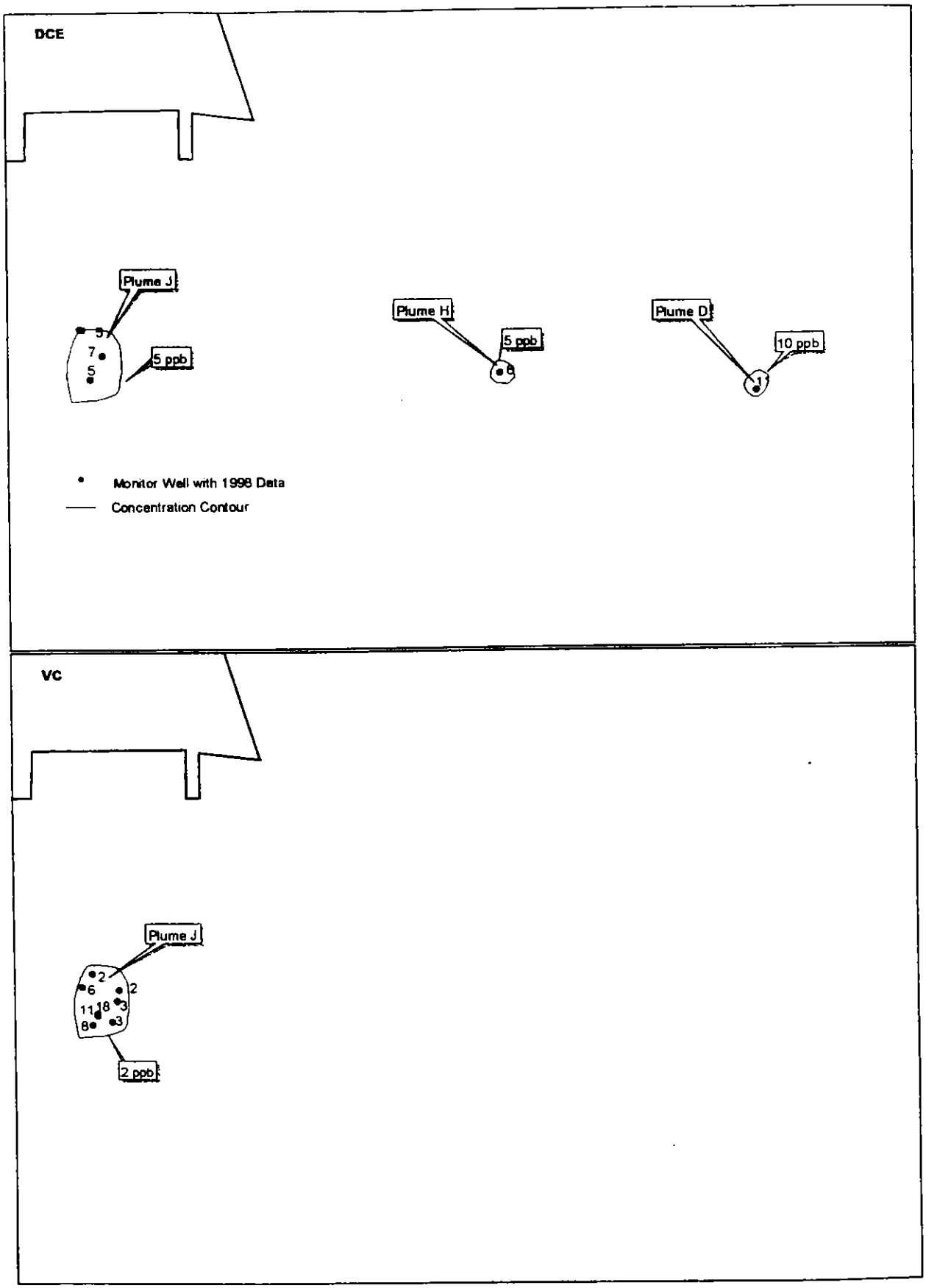


Figure 5-2b DCE and VC Concentrations and Contours for Plumes D-H-J

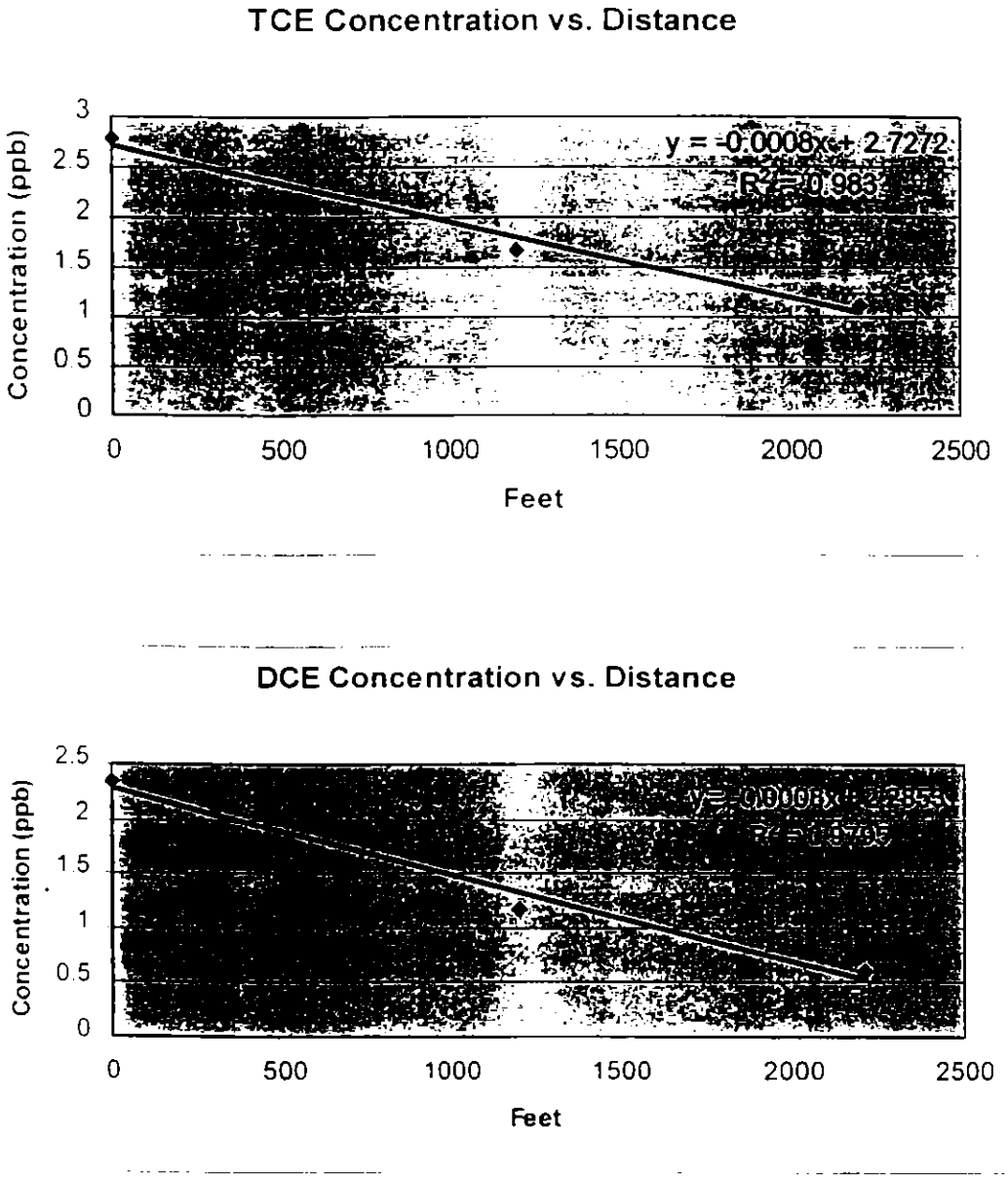


Figure 5-3 Concentration versus Distance Curve for TCE and DCE at Plume A.
Data used in the plot are from average of SS050MW044 and SS050MW471, SS050MW047, and SS050MW042.
They are generally along a flow path line in Figure 3-6.

6.0 SIMULATION OF FLOW FIELD FOR REMEDIATION OPTIONS

6.1 REMEDIATION OBJECTIVES

The proposed objectives for remediation of ground-water in the alluvial aquifer beneath Zone 5 plumes are as follows:

- Reduce contaminant plume migration and contain the plume within the base boundaries;

- Extract solvent contaminants from the alluvial aquifer in a manner which improves the quality of ground-water in this water-bearing zone to meet their Maximum Contaminant Levels (MCLs) implemented under Texas Risk Reduction Standard No. 2.

The MCLs for PCE, TCE. 1,2-cis DCE, and VC are 5 ppb, 5 ppb, 70 ppb, and 2 ppb, respectively.

Proposed remediation options for Zone 5 plumes consist of ground-water recovery and monitored natural attenuation. Natural attenuation can be simulated for contaminant fate and transport under ambient conditions without placement of any proposed recovery systems.

6.2 REMEDIATION EXTRACTION SYSTEMS FOR PLUME A

Currently, there is no active remediation system in Plume A. Six extraction well/trench networks were proposed to recover or contain the contaminated ground-water and prevent the contaminants from migrating off base to the east in the CH2M Hill CMS report. There is another Plume A component moving to the north off base, which will be dealt with separately. According to remediation alternative guidelines given in the CMS report, six extraction network systems were simulated, which included:

- A 1,000 ft source-area trench, located immediately downgradient of the high TCE and DCE concentration area;
- Perimeter control, a 3,000 ft trench or seven extraction wells along the base boundary;
- The off-base option, 12 extraction wells located approximately 1,000 feet from the base boundary;
- Source-area trench and perimeter wells, simulated concurrently; and
- Source-area trench, perimeter wells, and off-base wells simulated concurrently.

Details on remediation purposes, extraction network design and locations are given in the CH2M Hill CMS report. The following section summarizes simulated head and flow field for each extraction system.

6.3 SIMULATED PLUME A GROUND-WATER FLOW FIELDS

The zoom flow model presented in Section 3 was used to predict the changes in the ground-water flow patterns caused by the addition of extraction well/trench networks. Pumpage rates for each well were determined to maintain a saturated thickness of two feet in that well location. The model simulations were run under steady-state flow conditions. Figures 6-1 through 6-7 show the ground-water flow fields simulated for the baseline and six extraction systems. An associated summary table for each well network in the figures lists well names, locations, heads, and assigned pumpage rates.

6.3.1 Head and Flow Field under Ambient Conditions

Figure 6-1 shows simulated head and flow distributions under current ambient conditions as a baseline case. There are six Site S-1 extraction wells included in the baseline run. The primary objective of Site S-1 remediation system is to pump-and-treat chlorobenzene contaminated ground-water from a release. The pumping rates used for simulating flow field in the baseline run were based on the representative April-1999 data in Table 2-2. Because of the well locations and low pumping rates (a total of 1.3 gpm), there is virtually no effect on plume movement in the Plume A model domain, indicating that the baseline run simulated a natural ambient condition.

6.3.2 Head and Flow Field for Source-Area Trench Extraction System

Figure 6-2 shows simulated head and flow distributions for source-area trench extraction system. Trench locations are given in the CMS report. The 1,000 ft trench representing by twenty 50-foot model cells is located immediately downgradient of the suspected source area. The objective of this extraction system is to prevent the elevated concentration plume from moving further downgradient. Simulated total pumping rate is 4.4 gpm. The pumping rates (4.6 gpm) are only slightly increased when the saturated thickness was set at 1 foot. The low pumping rates are consistent with the higher elevation of Navarro Clay in that area. Compared to head contours of the baseline case, the drawdown generated by the simulated trench is approximately one foot in the corresponding trench locations.

6.3.3 Head and Flow Field for Perimeter Trench Extraction System

Figure 6-3 shows simulated head and flow distributions for the perimeter trench extraction system. A 3,000-ft trench represented by more that 60 model cells is designed for a purpose of containing the migrated plume on base. As described in the CMS report, the perimeter trench is located along the north end of east boundary of the base. The simulated total flow rates are 41.5 gpm.

6.3.4 Head and Flow Field for Perimeter Well Extraction System

Figure 6-4 shows simulated head and flow distributions for perimeter well extraction system. With the same remediation objective as the perimeter trench extraction system,

perimeter control was simulated with the seven extraction wells placing about 400 feet apart, instead of the 3,000-ft trench. The simulated total flow rates are 38.0 gpm.

6.3.5 Head and Flow Field for Off-Base Well Extraction System

Figure 6-5 shows simulated head and flow distributions for the off-base extraction system. 12 extraction wells placed about 400 feet apart were located north-south approximately 1000 feet from the base boundary. The objective for the off-base extraction system is to remove the contaminated ground-water in the off-base area. The simulated total flow rates are 62.6 gpm.

6.3.6 Head and Flow Field for Source-Area Trench and Perimeter Well Extraction System

Figure 6-6 shows simulated head and flow distributions for source-area trench and perimeter well extraction system. The separated source-area trench and perimeter well extraction systems was simulated concurrently for purpose of accelerating plume cleanup and control. The total flow rates are 23.9 gpm, slightly lower than the sum of two independent extraction systems.

6.3.7 Head and Flow Field for Source-Area Trench, Perimeter Well, and Off-Base Well Extraction System

Figure 6-7 shows simulated head and flow distributions for the source-area trench, perimeter well, and off-base well extraction system. The separated source-area trench, perimeter well, and off-base well extraction systems were simulated concurrently for the purpose of accelerating plume cleanup and control at on-base and off-base portions of the Plume A model domain. The total flow rates are 70.1 gpm, slightly lower than the sum of three independent extraction systems.

6.3.8 Flow Mass Balance for Simulated Plume A Extraction Systems

Table 6-1 summarizes the water balance for each simulation. The average mass balance error is about 1%.

Table 6-1
Calculated Ground-Water Fluxes (ft^3/day) for
Simulated Plume A Extraction Systems

Extraction System		Recharge	Wells	Model Boundary	Total Flux
Baseline (Site S-1 Wells)	In	24198	0	112460	136658
	Out	0	240	136630	136870
	Net	24198	-240	-24170	-212
	Mass Balance				-0.16%
Source Area Control	In	24198	0	112490	136688
	Out	0	840	136290	137130
	Net	24198	-840	-23800	-442
	Mass Balance				-0.32%
Perimeter Trench	In	24198	20	112560	136778
	Out	0	7975	135600	143575
	Net	24198	-7955	-23040	-6797
	Mass Balance				-4.97%
Perimeter Wells	In	24198	0	112510	136708
	Out	0	4037	135960	139997
	Net	24198	-4037	-23450	-3289
	Mass Balance				-2.41%
Off-Base Wells	In	24198	0	115560	139758
	Out	0	12047	129610	141657
	Net	24198	-12047	-14050	-1899
	Mass Balance				-1.36%
Source Control & Perimeter Wells	In	24198	20	112720	136938
	Out	0	4601	134080	138681
	Net	24198	-4581	-21360	-1743
	Mass Balance				-1.27%
Source, Perimeter & Off-Base Wells	In	24198	0	117010	141208
	Out	0	15226	127370	142596
	Net	24198	-15226	-10360	-1388
	Mass Balance				-0.98%

6.4 REMEDIATION EXTRACTION SYSTEMS FOR PLUMES D-H-J

Currently, there is no active remediation system for Plumes D-H-J. Ground-water recovery and monitored natural attenuation are proposed as remediation alternatives for Plumes D-H-J in the CMS report. The head and flow field presented in Section 4 included six MP/S-8 site extraction wells located in the southeast of the zoom model domain, which represents an ambient condition. Transport simulation under the ambient condition will be used to evaluate the natural attenuation option.

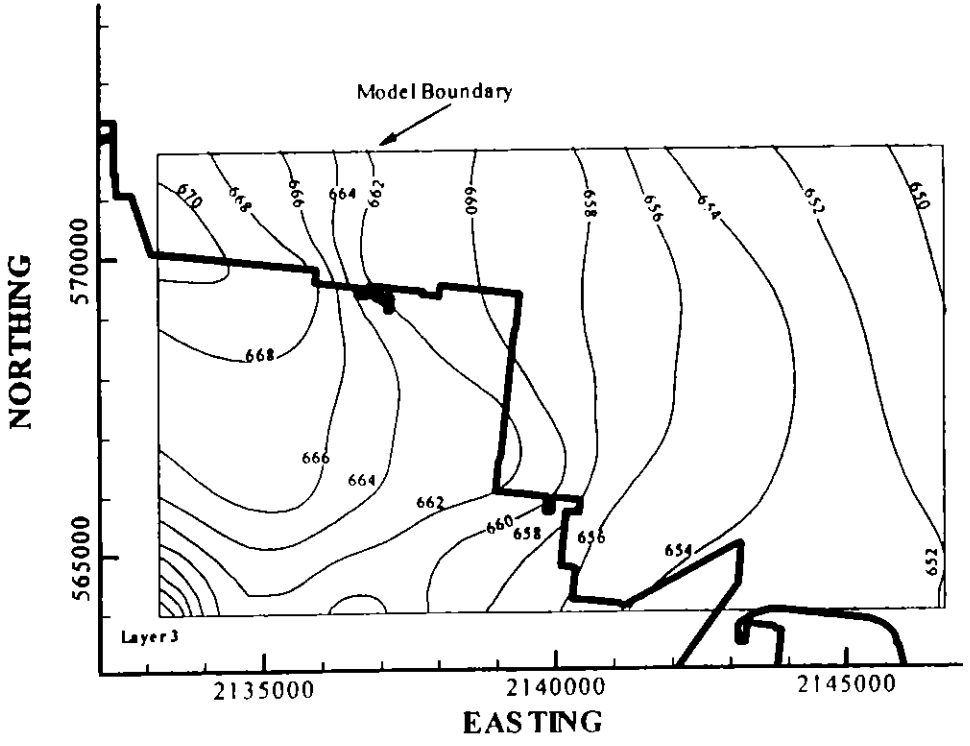
In addition to natural attenuation, there is an extraction system for each plume. Four extraction wells are proposed for Plume D. They are placed next to the well points with

elevated PCE or TCE concentrations. For Plume H, eight extraction wells, and for Plume J, 13 extraction wells are located downgradient from the front edge of the plumes. Figure 6-8 shows head and flow field for all five extraction systems. An associated table lists well numbers, easting, northing, head, and pumping rate. A subtotal for each extraction system is also provided in the table. Numbers and locations of all extraction wells are in the CMS report. Pumpage rates for each well were determined to maintain a saturated thickness of two feet in that well location. The model simulations were run under steady-state flow conditions.

Table 6-2 summarizes the water balance for the plume D-H-J flow simulation under pumping conditions. The two runs have similar mass balance error of 0.7 %.

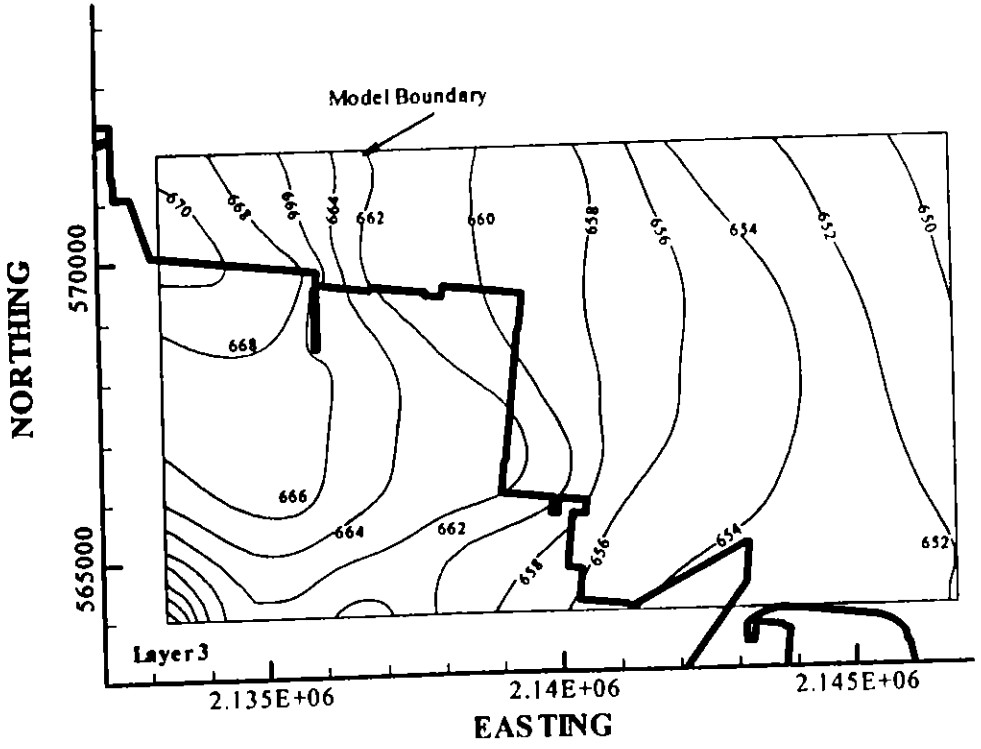
Table 6-2
Calculated Ground-Water Fluxes (ft^3/day) for
Simulated Plumes D-H-J Extraction Systems

	Recharge	River	Well	Model Boundary	Total Flux
Ambient Condition In	51062	32	0	144080	195174
Out	1372	23677	11716	159710	196475
Net	49690	-23645	-11716	-15630	-1301
Mass Balance					-0.67%
Pumping Condition In	51483	63	0	144570	196116
Out	1129	18643	30213	147460	197445
Net	50354	-18580	-30213	-2890	-1329
Mass Balance					-0.68%



Well Name	Easting (feet)	Northing (feet)	Well Head (feet)	Flow (gpm)
S1R112	2136649	569395	663.39	0.04
S1R115	2136749	569395	662.63	0.13
S1R114	2136949	569345	662.1	0.04
S1R116	2137049	569295	661.63	0.92
S1R111	2137149	569145	662.14	0.11
S1R113	2137149	569295	661.69	0.01
			Total Flow	1.25

Figure 6-1 Head and Flow Field under Ambient Conditions



Well Name	Easting (feet)	Northing (feet)	Well Head	Flow (gpm)
S_tmch_1	2135874	569495	663.41	0.29
S_tmch_2	2135874	569445	663.67	0.12
S_tmch_3	2135874	569395	663.8	0.11
S_tmch_4	2135874	569345	663.87	0.11
S_tmch_5	2135874	569295	663.9	0.11
S_tmch_6	2135874	569245	663.96	0.11
S_tmch_7	2135874	569195	663.94	0.11
S_tmch_8	2135874	569145	663.91	0.12
S_tmch_9	2135874	569095	663.88	0.13
S_tmch_10	2135874	569045	663.85	0.14
S_tmch_11	2135874	568995	663.83	0.17
S_tmch_12	2135874	568945	663.93	0.13
S_tmch_13	2135874	568895	663.91	0.16
S_tmch_14	2135874	568845	663.89	0.18
S_tmch_15	2135874	568795	663.87	0.19
S_tmch_16	2135874	568745	663.85	0.22
S_tmch_17	2135874	568695	663.83	0.27
S_tmch_18	2135874	568645	663.9	0.28
S_tmch_19	2135874	568595	663.88	0.38
S_tmch_20	2135874	568545	663.84	1.02
			Total Flow	4.37

Figure 6-2 Head and Flow for Source-Area Trench Extraction System

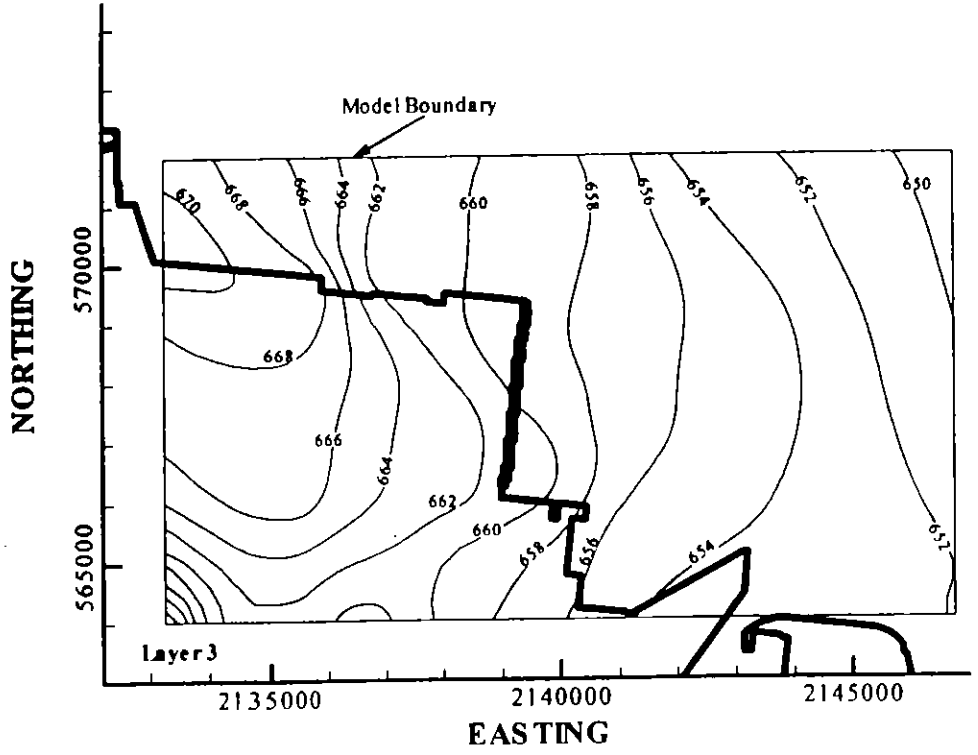
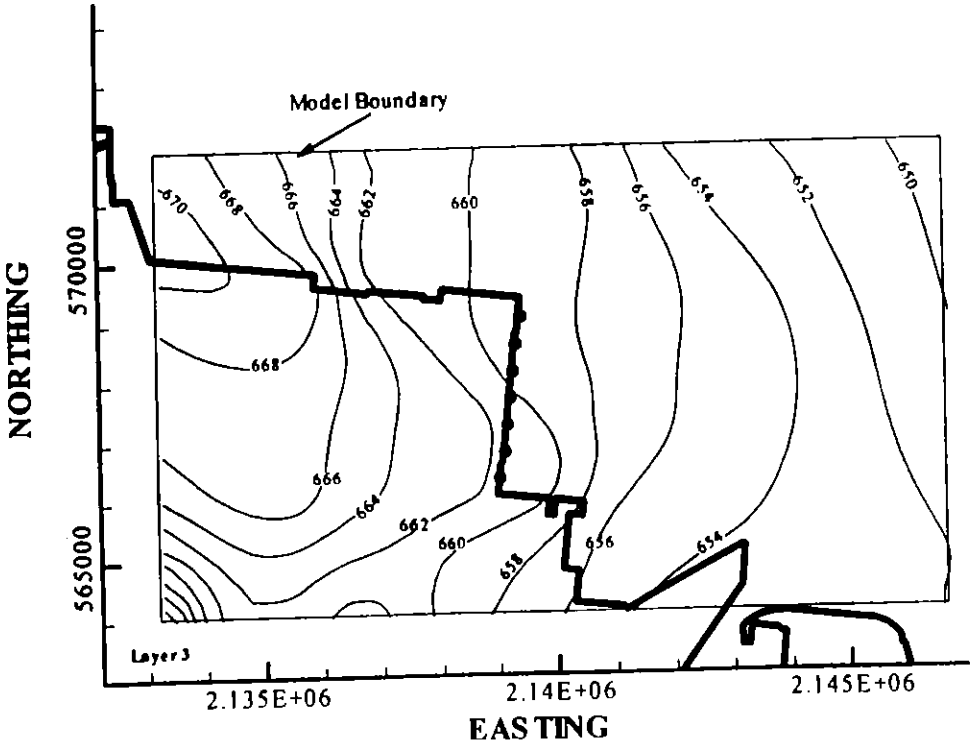


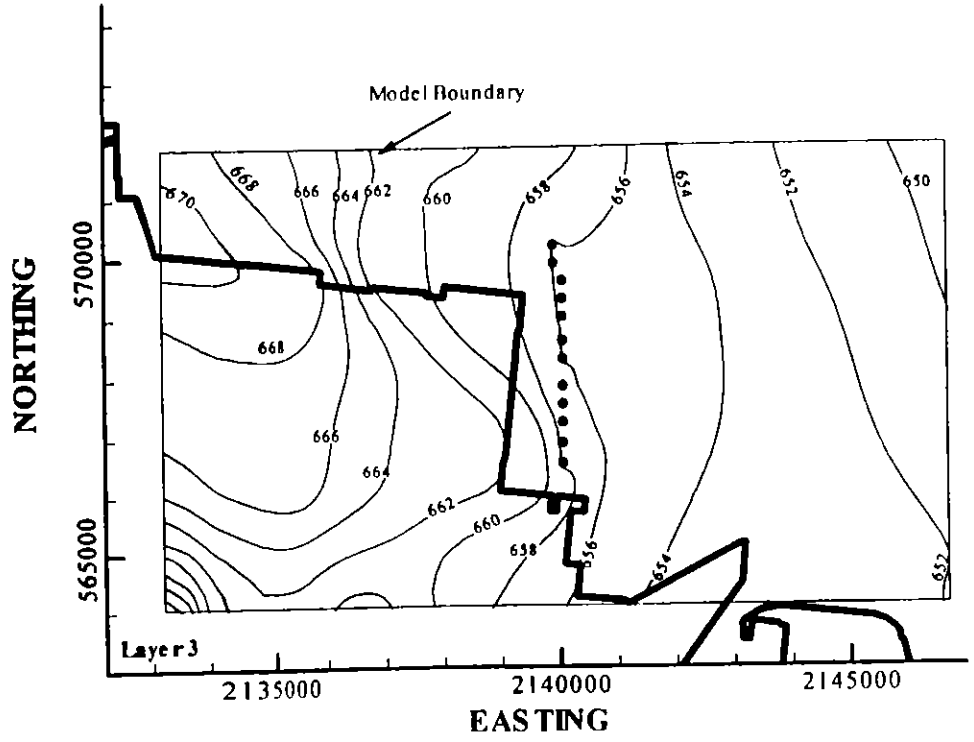
Figure 6-3 Head and Flow Field for Perimeter Trench Extraction System

Well Name	Easting (feet)	Northing (feet)	Well Head (feet)	Flow (gpm)
Peri_t_1	2139424	569295	658 12	7 27
Peri_t_2	2139424	569245	658 17	2 03
Peri_t_3	2139424	569195	658 18	1 76
Peri_t_4	2139424	569145	658 19	1 48
Peri_t_5	2139424	569095	658 2	1 30
Peri_t_6	2139424	569045	658 21	1 17
Peri_t_7	2139424	568995	658 21	1 43
Peri_t_8	2139374	568945	658 31	0 80
Peri_t_9	2139374	568895	658 31	0 66
Peri_t_10	2139374	568845	658 31	0 62
Peri_t_11	2139374	568795	658 31	0 54
Peri_t_12	2139374	568745	658 31	0 40
Peri_t_13	2139324	568695	658 34	0 45
Peri_t_14	2139324	568645	658 26	1 37
Peri_t_15	2139324	568595	658 26	0 87
Peri_t_16	2139324	568545	658 26	0 79
Peri_t_17	2139324	568495	658.27	0 73
Peri_t_18	2139324	568445	658.28	0 68
Peri_t_19	2139324	568395	658.3	0 63
Peri_t_20	2139274	568345	658 46	0 39
Peri_t_21	2139274	568295	658 49	0 38
Peri_t_22	2139274	568245	658 53	0 39
Peri_t_23	2139274	568195	658 57	0 40
Peri_t_24	2139274	568145	658.62	0 41
Peri_t_25	2139274	568095	658 68	0 64
Peri_t_26	2139274	568045	658 94	0.11
Peri_t_27	2139274	567995	659.02	0 14
Peri_t_28	2139274	567945	659 11	0 15
Peri_t_29	2139224	567895	659.27	0 38
Peri_t_30	2139224	567845	659.37	0 30
Peri_t_31	2139224	567795	659 47	0 39
Peri_t_32	2139224	567745	659.68	0 10
Peri_t_33	2139224	567695	659.79	0 20
Peri_t_34	2139224	567645	659.9	0 22
Peri_t_35	2139224	567595	600	0 24
Peri_t_36	2139224	567545	600.01	0 25
Peri_t_37	2139224	567495	600 19	0 27
Peri_t_38	2139174	567445	600 41	0 33
Peri_t_39	2139174	567395	600 5	0 25
Peri_t_40	2139174	567345	600 57	0 27
Peri_t_41	2139174	567295	600 61	0 30
Peri_t_42	2139174	567245	600 68	0 32
Peri_t_43	2139174	567195	600 73	0 32
Peri_t_44	2139174	567145	600 77	0 29
Peri_t_45	2139174	567095	600 81	0 27
Peri_t_46	2139174	567045	600 83	0 23
Peri_t_47	2139124	566995	600 89	0 62
Peri_t_48	2139124	566945	600 9	0 42
Peri_t_49	2139124	566895	600 9	0 24
Peri_t_50	2139124	566845	600.83	0 83
Peri_t_51	2139124	566795	600 82	0 64
Peri_t_52	2139124	566745	600 82	0 61
Peri_t_53	2139124	566695	600 81	0 59
Peri_t_54	2139124	566645	600.79	0 57
Peri_t_55	2139124	566595	600 78	0 79
Peri_t_56	2139074	566545	600 93	0 39
Peri_t_57	2139074	566495	600 91	0 36
Peri_t_58	2139074	566445	600 87	0 35
Peri_t_59	2139074	566395	600 84	0 36
Peri_t_60	2139024	566345	600 83	0 72
Peri_t_61	2139024	566295	600 78	0 93
			Total Flow	41 53



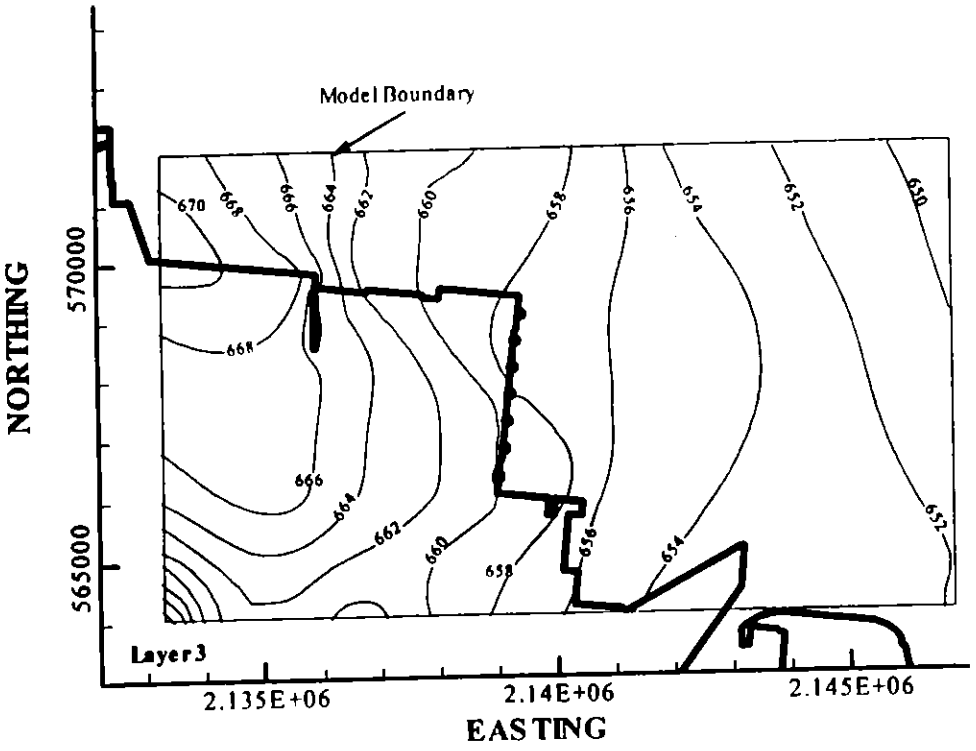
Well Name	Easting (feet)	Northing (feet)	Well Head (feet)	Flow (gpm)
Pen_RW-1	2139274	568295	657.92	14.51
Pen_RW_2	2139124	568795	658.01	8.04
Pen_RW_3	2139074	568495	658.53	2.99
Pen_RW_4	2139274	567945	659.84	1.73
Pen_RW_5	2139224	567595	660.79	2.37
Pen_RW_6	2139174	567245	660.78	5.51
Pen_RW_7	2139174	567045	660.92	2.86
			Total Flow	38.01

Figure 6-4 Head and Flow Field for Perimeter Well Extraction System



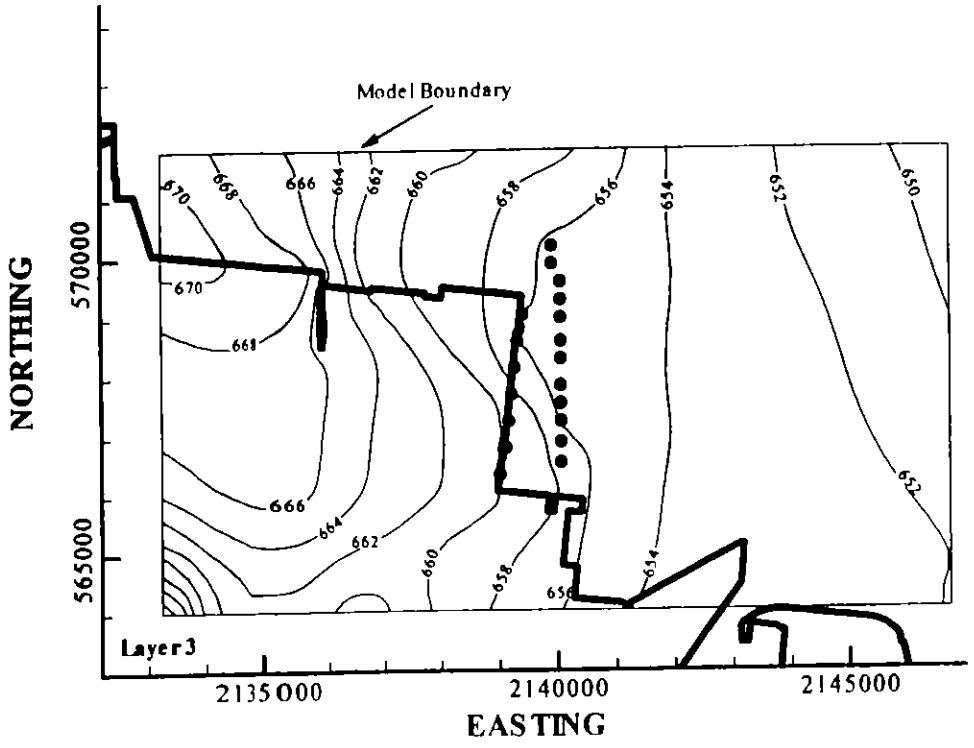
Well Name	Easting (feet)	Northing (feet)	Well Head (feet)	Flow (gpm)
Well_1	2139924	570195	654.93	20.43
Well_2	2140074	569595	655.03	8.60
Well_3	2139924	569895	655.39	8.48
Well_4	2140074	569295	655.21	5.89
Well_5	2140074	568995	655.39	4.30
Well_6	2140074	568595	655.46	3.48
Well_7	2140074	568295	655.55	2.76
Well_8	2140074	567845	655.78	2.17
Well_9	2140074	566545	655.94	1.95
Well_10	2140074	566895	655.18	1.65
Well_11	2140074	567545	655.89	1.63
Well_12	2140074	567245	656.06	1.24
			Total Flow	62.58

Figure 6-5 Head and Flow Field for Off-Base Well Extraction System



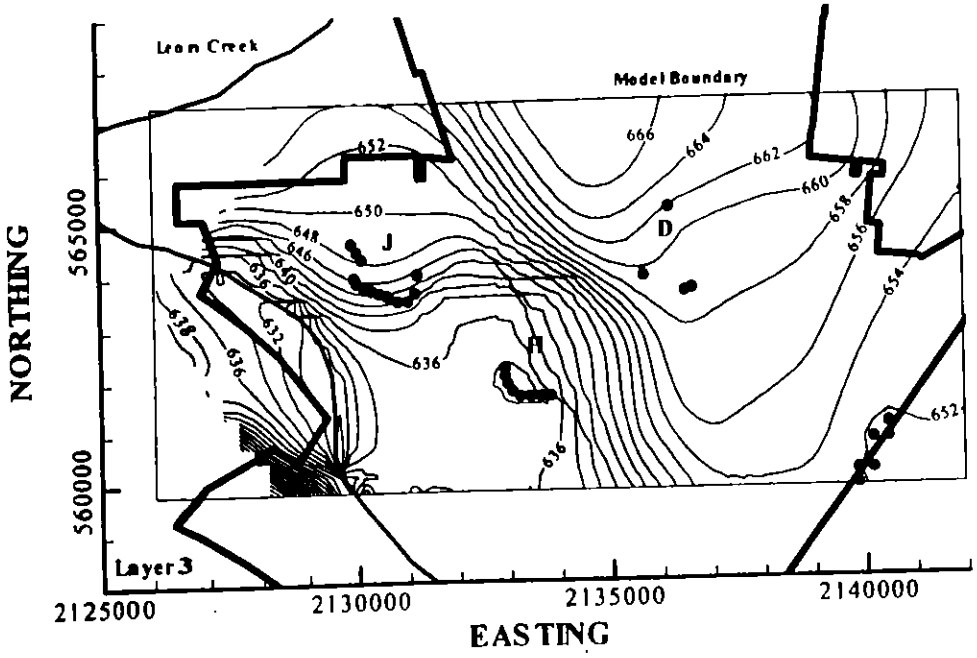
Well Name	Easting (feet)	Northing (feet)	Well Head (feet)	Flow (gpm)
Peri_RW-1	2139274	568295	654.29	14.04
Peri_RW_2	2139124	566795	654.30	7.82
Peri_RW_3	2139074	566495	655.29	5.32
Peri_RW_4	2139274	567945	654.88	2.92
Peri_RW_5	2139224	567595	657.23	2.75
Peri_RW_6	2139174	567245	656.59	2.30
Peri_RW_7	2139174	567045	656.12	1.69
S_trnch_1	2135874	569495	662.78	0.30
S_trnch_2	2135874	569445	662.92	0.13
S_trnch_3	2135874	569395	662.99	0.11
S_trnch_4	2135874	569345	663.02	0.11
S_trnch_5	2135874	569295	663.01	0.12
S_trnch_6	2135874	569245	663.10	0.11
S_trnch_7	2135874	569195	663.05	0.12
S_trnch_8	2135874	569145	663.00	0.13
S_trnch_9	2135874	569095	662.94	0.13
S_trnch_10	2135874	569045	662.89	0.15
S_trnch_11	2135874	568995	662.86	0.17
S_trnch_12	2135874	568945	663.00	0.14
S_trnch_13	2135874	568895	662.97	0.17
S_trnch_14	2135874	568845	662.93	0.18
S_trnch_15	2135874	568795	662.90	0.20
S_trnch_16	2135874	568745	662.88	0.23
S_trnch_17	2135874	568695	662.85	0.26
S_trnch_18	2135874	568645	662.85	0.31
S_trnch_19	2135874	568595	662.83	0.41
S_trnch_20	2135874	568545	662.80	1.09
			Total Flow	41.38

Figure 6-6 Head and Flow Field for Source-Area Trench and Perimeter Well Extraction System



Well Name	Easting (feet)	Northing (feet)	Well Head (feet)	Flow (gpm)
S_trnch_1	2135874	569495	662.89	0.29
S_trnch_2	2135874	569445	663.05	0.13
S_trnch_3	2135874	569395	663.11	0.11
S_trnch_4	2135874	569345	663.14	0.11
S_trnch_5	2135874	569295	663.14	0.12
S_trnch_6	2135874	569245	663.23	0.11
S_trnch_7	2135874	569195	663.18	0.12
S_trnch_8	2135874	569145	663.12	0.12
S_trnch_9	2135874	569095	663.06	0.13
S_trnch_10	2135874	569045	663.01	0.14
S_trnch_11	2135874	568995	662.96	0.17
S_trnch_12	2135874	568945	663.09	0.14
S_trnch_13	2135874	568895	663.06	0.16
S_trnch_14	2135874	568845	663.02	0.18
S_trnch_15	2135874	568795	662.98	0.20
S_trnch_16	2135874	568745	662.95	0.22
S_trnch_17	2135874	568695	662.93	0.26
S_trnch_18	2135874	568645	662.93	0.31
S_trnch_19	2135874	568595	662.91	0.40
S_trnch_20	2135874	568545	662.88	1.09
Peri_RW-1	2139274	568295	656.06	5.39
Peri_RW_2	2139124	566795	654.26	4.64
Peri_RW_3	2139074	566495	656.91	2.15
Peri_RW_4	2139274	567945	654.06	1.47
Peri_RW_5	2139224	567595	655.17	2.13
Peri_RW_6	2139174	567245	655.38	4.88
Peri_RW_7	2139174	567045	655.29	2.60
Well_1	2139924	570195	653.25	21.62
Well_2	2140074	569595	653.64	8.13
Well_3	2139924	569895	652.94	7.70
Well_4	2140074	569295	653.16	4.34
Well_5	2140074	568995	653.62	2.38
Well_6	2140074	568595	653.84	1.69
Well_7	2140074	568295	655.21	1.30
Well_8	2140074	567845	654.01	1.10
Well_9	2140074	566545	657.83	0.78
Well_10	2140074	566895	658.02	0.57
Well_11	2140074	567545	657.83	0.81
Well_12	2140074	567245	658.35	1.13
			Total Flow	79.31

Figure 6-7 Head and Flow Field for Source-Area Trench, Perimeter Well, and Off-Base Well Extraction System



Plumes	Well Name	Easting (feet)	Northing (feet)	Well Head	Flow (gpm)
MP Site	MP-1	2140449	561020	651.34	30.45
	MP_2	2140149	560720	651.3	16.86
	MP_3	2140449	560720	651.33	5.71
Site S-8	S8_4	2139849	560120	652.08	1.79
	S8_5	2140149	560120	651.51	3.41
	S8_6	2139849	559820	651.67	2.64
				Sub Total	60.86
Plume D	RW-D1	2136174	565195	657.98	3.98
	RW-D2	2135674	563895	653.69	1.16
	RW-D3	2136624	563645	653.42	1.88
	RW_D4	2130624	563595	653.42	1.54
				Sub Total	8.57
Plume H	RW_H1	2132924	562195	632.26	18.28
	RW-H2	2132924	562045	631.75	12.50
	RW_H3	2132974	561895	631.75	7.76
	RW_H4	2133074	561745	630.8	10.90
	RW_H5	2133224	561645	631.21	6.85
	RW_H6	2133424	561645	631.59	4.94
	RW_H7	2133624	561645	631.59	7.18
	RW_H8	2133824	561645	632.53	5.22
				Sub Total	73.63
Plume J	RW_J1	2129924	564595	643.57	0.47
	RW_J2	2130024	564445	641.82	0.68
	RW_J3	2130124	564295	641.96	0.71
	RW_J4	2131224	563995	641.5	1.54
	RW_J5	2129974	563945	639.43	0.31
	RW_J6	2130024	563845	636.45	1.17
	RW_J7	2130174	563745	637.14	1.07
	RW_J8	2130324	563695	637.14	1.20
	RW_J9	2131174	563645	637.8	0.76
	RW_J10	2130474	563645	638	2.01
	RW_J11	2136474	563595	637.4	0.78
	RW_J12	2130824	563495	637	0.56
	RW_J13	2131024	563495	636.67	2.66
				Sub Total	13.89
				Total Flow	156.95

Figure 6-8 Head and Flow Field for Plumes D-H-J Well Extraction System

7.0 EVALUATION OF REMEDIATION EXTRACTION SYSTEMS

7.1 TRANSPORT MODEL SET-UP

The aquifer and chemical parameters associated with the transport model are presented in Sections 3, 4, and 5. All of the simulations included adsorption, dispersion, and biodegradation for TCE. DCE, and VC for Plume A, and PCE, TCE, DCE, and VC for Plumes D-H-J. Every transport simulation was run for 30 years. For every model time-step interval, a comprehensive mass balance was calculated. The initial time interval was set to 0.0001 days and the maximum time interval was set to 20 days. Complete concentration distributions for all four chlorinated solvents were saved at 0.5 year intervals. For a single model run, the total amount of computer hard-drive space for input, output, and processing space is about 400 megabytes.

7.1.1 Initial Contaminant Distribution

The initial dissolved ground-water concentrations for model input were based on the contour maps generated by interpolating the maximum 1998 concentration data points within the zoom transport model domain. Figures 7-1 and 7-2 show initial contaminant concentration distributions for Plume A, and Plumes D-H-J, respectively. The concentration contours were determined from solvent data presented in Figures 5-1 and 5-2. Initial mass distribution for the four species is based on interpolation between the contours. For instance, between the 0 (i.e. no detect) and 5 ppb contours, the concentration values range between 0 and 5 ppb. For the area enclosed by the highest concentration contours, individual concentration values measured at wells are included so that concentration values above the highest contour are accurately represented in the model.

The allocation of the initial contaminant mass based on the concentration contours was performed differently for the layers of the models that correlated with the saturated and unsaturated layers. The saturated portion of the aquifer is defined as the aquifer volume above the model's bottom boundary and below the water table. Across most of the plume site, the water table resides in Model Layers 2. As a result, Model Layers 3 and 4 represent the saturated portion of the aquifer. Within the saturated portion of the aquifer, contaminant mass was assigned to the aquifer deposits and to the ground-water. Contaminant mass is initially placed onto the soil because the ground-water is presumed to remain in equilibrium with the aquifer deposits at all times. As discussed in Section 5.1.3 this equilibrium is different for each contaminant. Within the saturated zone, the amount of contaminant mass assigned to the aquifer deposit equals the product of the contaminant's retardation factor and the ground-water contaminant mass. Across most of the area where ground-water contaminants have been detected, the thickness of the two model layers range between 2 and 4 feet.

Tables 7-1 and 7-2 provide a breakdown of the initial contaminant mass in the model for the Plume A and Plumes D-H-J, respectively. Table 7-3 provides initial mass distributions divided for each plume: Plume D, Plume H, and Plume J in the Plumes D-

H-J model domain. No residual or free-phase PCE and TCE was considered for any of the model simulations. The purpose of the remediation extraction systems was to reduce concentrations hydraulically down-gradient from any possible existing PCE sources.

Table 7-1
Distribution of Mass (Kg) Within the Initial Contaminant Plume A

Saturated Zone	Layer	Well	Total by Species
TCE MASS IN WATER:	22.45	23.66	
TCE MASS IN SOIL:	8.44	8.45	
Total TCE	30.89		63.00
DCE MASS IN WATER:	4.51	4.72	
DCE MASS IN SOIL:	1.15	1.15	
Total DCE	5.66		11.52
VC MASS IN WATER:	0.01	0.01	
VC MASS IN SOIL:	0.00	0.00	
Total VC	0.01	0.01	0.02
Total Solvent			74.54

Table 7-2
Distribution of Mass (Kg) Within the Initial Contaminant Plumes D-H-J

Saturated Zone	Layer	Well	Total by Species
PCE MASS IN WATER:	8.21	5.47	
PCE MASS IN SOIL:	2.46	1.51	
Total PCE	10.67		17.65
TCE MASS IN WATER:	0.99	1.26	
TCE MASS IN SOIL:	0.53	0.53	
Total TCE	1.52	1.79	3.31
DCE MASS IN WATER:	0.07	0.07	
DCE MASS IN SOIL:	0.02	0.02	
Total DCE	0.09	0.09	0.18
VC MASS IN WATER:	0.06	0.05	
VC MASS IN SOIL:	0.02	0.02	
Total VC	0.08	0.07	0.14
Total Solvent			21.28

Table 7-3

Contaminant Mass (Kg) Divided by the Plume within the Plumes D-H-JTransport Model Domain

Plumes	Species	Mass in Water	Mass on Solids	Total
[illegible]	PCE	[illegible]	[illegible]	[illegible]
	TCE	1.62	0.66	2.28
	DCE	0.03	0.01	0.04
	VC	0.00	0.00	0.00
				18.50
[illegible]	PCE	0.00	0.00	0.00
	TCE	0.62	0.39	1.02
	DCE	0.01	0.00	0.02
	VC	0.00	0.00	0.00
				1.04
[illegible]	PCE	[illegible]	[illegible]	[illegible]
	TCE	0.00	0.00	0.00
	DCE	0.10	0.03	0.13
	VC	0.11	0.03	0.14
				1.74
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

7.1.2 Biodegradation Rates

All of the respective model simulations assumed a half-life of 8 years, 6 years, 4 years, and 1 year for PCE, TCE, DCE, and VC, respectively.

7.2 SIMULATION RESULTS OF ZOOM TRANSPORT MODEL

The model results are summarized using plots of concentration distributions at 5-year time intervals and plots that summarize the components of a cumulative mass balance for the entire 30-year simulations. The concentration plots show the area enclosed by the MCL levels of 5 ppb, 5 ppb, 70 ppb, and 2 ppb for PCE, TCE, DCE, and VC, respectively. An MCL of 70 ppb is being used for DCE because field data indicates that the vast majority of DCE is in the form of cis 1,2 DCE. In order to clearly show the area of the plume that exceeds MCLs, plots of each contaminant species has been cut off at their respective MCL limits. The cumulative mass balance plots show the importance of biodegradation and extraction wells for removing contaminant mass at early and late stages.

In order to help minimize the number of figures, concentration plots are provided for only Model Layer 4. For all times, the concentration levels in Model Layers 1 and 2 are lower than those for Model Layer 4. Comparison of results for Model Layers 3 and 4 show that their concentration distributions are identical for all practical purposes.

7.2.1 Simulation Results of Plume A Transport Model

7.2.1.1 Concentration Plots for Every 5 years

As can be noted by comparing the numerous plots, the results of several extraction systems for Plume A are very similar. Where similar results have been obtained, a complete set of results is provided for each option for completeness. Figures 7-3 to 7-23 provide concentration distributions for TCE, DCE, and VC for all one baseline and six extraction systems at 5-year interval beginning with the 5^{th} year for 30 years. All contamination is gone at 30 years. A 30-year plot is provided to illustrate completeness

The results for all of the remediation options have identical plots for DCE. These plots show no DCE concentrations are above 70 ppb at and beyond the 15-year period. Although these plots appear identical, the options do provide different DCE plumes over time but these DCE concentrations are less than 70 ppb and are therefore not shown.

For evaluation of the six extraction systems, simulation under ambient conditions provided a baseline for comparison (Figures 7-3 to 7-5). At ambient case, both on-base and off-base portions of TCE and VC plumes have persisted beyond 20 to 25 year ranges. On TCE and VC at 25-year plots, only a few cells with concentrations slightly higher than its MCL values, those above MCL concentration cells don't show in the plots.

Figures 7-6 to 7-8 show simulated TCE, DCE, and VC concentrations for the source-area trench extraction system. TCE and VC have essentially dissipated from on-base and off-base portion of the Plume A domain by 20 years and 25 years, respectively.

Figures 7-9 to 7-11 and Figures 7-12 to 7-13 show simulated TCE, DCE, and VC concentrations for the perimeter trench and perimeter well extraction systems, respectively. Simulated TCE and VC concentrations are essentially the same for these two perimeter control extraction systems. On 15-year plots, most off-base TCE and VC are gone, while TCE and VC have persisted on base beyond 25 years.

Figures 7-14 to 7-16 show simulated TCE, DCE, and VC for the off-base well extraction system. On on-base portion of the Plume A model domain, simulated TCE and VC concentrations are similar to two perimeter control system, plume persisting beyond 25 years. On off-base portion of the Plume A model domain, TCE and VC plumes have been contained along the off-base extraction well line, rather than on the base boundary as in two perimeter control simulations.

Figures 7-17 to 7-19 show simulated TCE, DCE, and VC for the source-area trench and perimeter well extraction system. Simulated TCE and VC concentrations look like combined source-area trench and perimeter well systems. Both on-base and off-base TCE plume has dissipated, but VC plume has still persisted, in the 20-year plots.

Figures 7-20 to 7-22 show simulated TCE, DCE, and VC for the source-area trench, perimeter well, and off-base well extraction system. Simulated TCE and VC

concentrations look like combined source-area trench and off-base well systems. Both on-base and off-base TCE plumes have dissipated, but VC plume has still persisted in the 20-year plots.

7.2.1.2 Time to Attain MCLs for TCE, DCE, and VC Concentrations

Figures 7-3 through 7-23 provide useful information regarding the size of the simulated solvent plumes for a 30-year period. However, because the data is in 5-year increments, the time to reach the MCLs for each compound cannot be accurately estimated. In cases where slightly above MCLs are within limited cell locations, concentration contours may not be shown in the 5-year interval plots. In order to provide accurate estimates for these times, Figures 7-24 through 7-30 have been created. These figures show the change in the maximum concentration of each compound over time for the portions of the plume on and off base. The time at which the maximum concentration has dropped below its MCL is represented by the intercept of the data line and the concentration line representing the MCL. These times are summarized in Table 7-4

For all stand-alone extraction systems and the baseline ambient case, the MCLs are reached off-base before they are reached on-base. Although there are differences among the extraction systems with regard to the time to reach the MCLs, these differences are relatively minor. For TCE, the differences in the time to reach the MCLs off-base are within three years (from 17 to 20 years). For simulations with the source-area trench system on, the MCL reaching time on base is approximately 20 years, compared to 26 years for the extraction systems without the source-area trench. For DCE, all simulations indicated that the plume has not, and will not move off base. The time range to reach the MCLs on base is from 10 to 13 years. For VC simulations with the source-area trench included, the time to reach the MCL for the on-base portion of the plume is 21 to 22 years, compared to 27 to 29 years for the extraction systems without the source-area trench included. For the off-base portion of VC plume, the time to reach the MCL is from 18 to 21 years with a perimeter or off-base control component included, otherwise, the time to reach MCL would be 26 years for the source-area trench control only or under ambient conditions.

Table 7-4
Time for the Maximum Concentration to Reach the MCLs Based on Simulations

Alternative	Time to MCL (years)					
	TCE (5 ppb)		DCE (70 ppb)		VC (2 ppb)	
	On Base	Off Base	On Base	Off Base	On Base	Off Base
Baseline	26	20	13.5	0	29	26
Source-Area Trench	20.5	20	10.5	0	22	26
Perimeter Trench	26	17	13	0	28	18
Perimeter Wells	26	18	13	0	27	18
Off-Base Wells	26	18	13	0	28	20
Source-Area Trench and Perimeter Wells	20	19	10.2	0	21	21
Source-Area Trench, Perimeter Wells, and Off-Base Wells	20	19	10.2	0	21	21

7.2.1.3 Cumulative Mass Balance for Total Solvents

Figure 7-31 shows the total mass removal of contaminants over 30 year for baseline and six extraction systems. The total mass removal is calculated by summing the total mass removed by the wells and the mass of VC lost to biodegradation. For all of the options, the mass removal curves approximate an exponential function with the curve becoming asymptotic to a maximum value after about 20 years. With respect to total mass removed over time, all of the options have similar results as the maximum difference among the alternatives does not exceed more than 20 kg (about 25% initial plume mass) at any given time. As should be expected, two perimeter extraction systems, and two concurrently simulated source-area, perimeter well with or without off-base well, have essentially identical mass removal curves, respectively.

Figure 7-32 shows the mass removal caused by extraction of contaminants over 30 years for all six extraction systems. Two concurrently simulated source-area, perimeter well with or without off-base well recovers the greatest contaminant mass. Figure 7-33 shows the mass removal caused by naturally-occurring biodegradation for all contaminants for

the baseline and six extraction systems. After 30-years, the total mass removed by naturally-occurring biodegradation ranges from about 36 kg to 68 kg. As expected, the greatest biodegradation occurs for the baseline and source-area trench cases because they have less wells than the other five extraction systems.

Figure 7-34 shows the importance of pumping from well and biodegradation for removing contaminant mass. Except for two concurrently simulated source-area, perimeter well with or without off-base well. biodegradation has removed more mass than the wells do. For all extraction systems except for the source-area trench, the contribution of biodegradation to total mass removal increases over time but approaches an asymptotic value at about 15 to 20 years.

Tables 7-5 and 7-6 present a summary of the total mass removed by each well for the baseline and six extraction systems for 5 and 30 years. After 5 years of simulation, the percentages of mass removal range from 15% for the baseline to 33-34% for two concurrently simulated source-area, and perimeter well with or without off-base well systems. After 30 years of simulation, the percentages of mass removal range from 91% for the baseline to 97% for two concurrently simulated source-area, and perimeter well with or without off-base well systems. The tables show that for all options, the mass removal among the wells spans more than two orders of magnitude. For instance, for all extraction system with the perimeter wells included, Well No. Peri_RW_2 consistently removes 20-40% of the total mass by well in a corresponding system. The Table thus provides information to help well location for maximum removal of contaminant mass.

7.2.2 Simulation Results of Plumes D-H-J Transport Model

7.2.2.1 Concentration Plots for Every 5 years

Figures 7-35 to 7-42 provide concentration distributions for PCE, TCE, DCE, and VC for ambient and pumping conditions in the Plumes D-H-J model domain at 5-year interval beginning with the 5th year for 30 years. All contamination is gone by the Year 30. The purpose to show a 30 year plot is for completeness.

Figures 7-35 to 7-38 show simulated PCE, TCE, DCE, and VC under ambient conditions. On the 5-year plots, low concentrations of PCE originated from Plume J and TCE from Plume H have reduced in size; however, PCE and TCE at Plume D indicate spreading due to high initial point concentrations. The spreading is following the ground-water flow directions. PCE at Plume J and TCE at Plume H have dissipated by the 10-year, but both PCE and TCE have persisted in Plume D beyond the 25 years. On VC at 25-year plots, only a few cells with concentrations higher than its MCL values; those above MCL concentration cells aren't shown in the plots.

Figures 7-39 to 7-38 show simulated PCE, TCE, DCE, and VC concentrations under pumping conditions, respectively. Only Plume D is showing up in those plots. On 20-year plots, PCE, TCE, VC have essentially dissipated.

Table 7-5
Summary of Mass(Kg) Removed After 5 Years of Simulation

Baseline		Source Area Control		Perimeter Trench		Perimeter Well		Offbase Wells		Source and Perimeter Well		Source, Perimeter and Offbase Wells	
S1R112	0.00	S_trnch_1	0.04	Peri_t_1	0.00	Peri_RW-1	0.80	Well_1	0.00	Peri_RW-1	0.38	S_trnch_1	0.04
S1R115	0.00	S_trnch_2	0.04	Peri_t_2	0.01	Peri_RW_2	2.97	Well_2	0.05	Peri_RW_2	3.31	S_trnch_2	0.04
S1R114	0.00	S_trnch_3	0.05	Peri_t_3	0.02	Peri_RW_3	1.57	Well_3	0.00	Peri_RW_3	1.80	S_trnch_3	0.05
S1R116	0.00	S_trnch_4	0.06	Peri_t_4	0.04	Peri_RW_4	0.94	Well_4	0.39	Peri_RW_4	2.06	S_trnch_4	0.06
S1R111	0.00	S_trnch_5	0.08	Peri_t_5	0.06	Peri_RW_5	1.03	Well_5	0.79	Peri_RW_5	0.25	S_trnch_5	0.09
S1R113	0.00	S_trnch_6	0.09	Peri_t_6	0.09	Peri_RW_6	1.56	Well_6	0.96	Peri_RW_6	1.36	S_trnch_6	0.09
		S_trnch_7	0.12	Peri_t_7	0.16	Peri_RW_7	0.33	Well_7	0.79	Peri_RW_7	1.25	S_trnch_7	0.13
		S_trnch_8	0.15	Peri_t_8	0.12			Well_8	0.41	S_trnch_1	0.04	S_trnch_8	0.16
		S_trnch_9	0.17	Peri_t_9	0.12			Well_9	0.01	S_trnch_2	0.04	S_trnch_9	0.19
		S_trnch_10	0.22	Peri_t_10	0.13			Well_10	0.08	S_trnch_3	0.05	S_trnch_10	0.24
		S_trnch_11	0.29	Peri_t_11	0.13			Well_11	0.15	S_trnch_4	0.07	S_trnch_11	0.31
		S_trnch_12	0.23	Peri_t_12	0.10			Well_12	0.07	S_trnch_5	0.09	S_trnch_12	0.26
		S_trnch_13	0.25	Peri_t_13	0.15					S_trnch_6	0.09	S_trnch_13	0.27
		S_trnch_14	0.25	Peri_t_14	0.47					S_trnch_7	0.13	S_trnch_14	0.27
		S_trnch_15	0.27	Peri_t_15	0.36					S_trnch_8	0.16	S_trnch_15	0.28
		S_trnch_16	0.30	Peri_t_16	0.36					S_trnch_9	0.19	S_trnch_16	0.31
		S_trnch_17	0.36	Peri_t_17	0.36					S_trnch_10	0.24	S_trnch_17	0.36
		S_trnch_18	0.36	Peri_t_18	0.34					S_trnch_11	0.31	S_trnch_18	0.40
		S_trnch_19	0.46	Peri_t_19	0.40					S_trnch_12	0.26	S_trnch_19	0.50
		S_trnch_20	1.11	Peri_t_20	0.25					S_trnch_13	0.27	S_trnch_20	1.21
				Peri_t_21	0.24					S_trnch_14	0.27	Peri_RW-1	0.48
				Peri_t_22	0.25					S_trnch_15	0.28	Peri_RW_2	2.46
				Peri_t_23	0.24					S_trnch_16	0.32	Peri_RW_3	1.57
				Peri_t_24	0.24					S_trnch_17	0.37	Peri_RW_4	1.07
				Peri_t_25	0.34					S_trnch_18	0.41	Peri_RW_5	1.23
				Peri_t_26	0.00					S_trnch_19	0.50	Peri_RW_6	1.67
				Peri_t_27	0.08					S_trnch_20	1.21	Peri_RW_7	0.24
				Peri_t_28	0.09							Well_1	0.00
				Peri_t_29	0.25							Well_2	0.00
				Peri_t_30	0.19							Well_3	0.00
				Peri_t_31	0.25							Well_4	0.08
				Peri_t_32	0.07							Well_5	0.27
				Peri_t_33	0.13							Well_6	0.43
				Peri_t_34	0.14							Well_7	0.43
				Peri_t_35	0.14							Well_8	0.19
				Peri_t_36	0.14							Well_9	0.06
				Peri_t_37	0.14							Well_10	0.04
				Peri_t_38	0.19							Well_11	0.04
				Peri_t_39	0.14							Well_12	0.00
				Peri_t_40	0.15								
				Peri_t_41	0.16								
				Peri_t_42	0.16								
				Peri_t_43	0.16								
				Peri_t_44	0.14								
				Peri_t_45	0.12								
				Peri_t_46	0.09								
				Peri_t_47	0.27								
				Peri_t_48	0.17								
				Peri_t_49	0.09								
				Peri_t_50	0.30								
				Peri_t_51	0.21								
				Peri_t_52	0.19								
				Peri_t_53	0.17								
				Peri_t_54	0.14								
				Peri_t_55	0.16								
				Peri_t_56	0.09								
				Peri_t_57	0.07								
				Peri_t_58	0.06								
				Peri_t_59	0.05								
				Peri_t_60	0.09								
				Peri_t_61	0.05								
Well Losses	0.00		4.89		9.99		9.20		3.70		15.71		15.51
Decay Losses	11.43		10.41		10.57		10.65		11.11		9.39		9.42
Total Losses	11.43		15.29		20.57		19.86		14.81		25.10		24.93
% removed	15.33%		20.52%		27.59%		26.64%		19.86%		33.67%		33.45%
% remaining	84.67%		79.48%		72.41%		73.36%		80.14%		66.33%		66.55%

Table 7-6
Summary of Mass Removed After 30 Years of Simulation

Baseline		Source Area Control		Perimeter Trench		Perimeter Well		Offbase Well		Source and Perimeter Well		Source, Perimeter and Offbase Wells	
S1R11	0.00	S_trnch_1	0.09	Peri_t_1	0.05	Peri_RW-1	3.72	Well_1	0.07	Peri_RW-1	1.20	S_trnch_1	0.09
S1R11	0.01	S_trnch_2	0.08	Peri_t_2	0.05	Peri_RW_	9.72	Well_2	0.98	Peri_RW_	10.67	S_trnch_2	0.08
S1R11	0.00	S_trnch_3	0.11	Peri_t_3	0.10	Peri_RW_	3.86	Well_3	0.04	Peri_RW_	3.00	S_trnch_3	0.11
S1R11	0.06	S_trnch_4	0.13	Peri_t_4	0.17	Peri_RW_	1.89	Well_4	3.92	Peri_RW_	5.49	S_trnch_4	0.14
S1R11	0.01	S_trnch_5	0.17	Peri_t_5	0.27	Peri_RW_	1.85	Well_5	5.02	Peri_RW_	0.39	S_trnch_5	0.18
S1R11	0.00	S_trnch_6	0.19	Peri_t_6	0.38	Peri_RW_	2.52	Well_6	4.13	Peri_RW_	2.67	S_trnch_6	0.19
		S_trnch_7	0.25	Peri_t_7	0.67	Peri_RW_	0.57	Well_7	2.69	Peri_RW_	2.76	S_trnch_7	0.26
		S_trnch_8	0.34	Peri_t_8	0.50			Well_8	1.50	S_trnch_1	0.09	S_trnch_8	0.35
		S_trnch_9	0.43	Peri_t_9	0.50			Well_9	0.22	S_trnch_2	0.09	S_trnch_9	0.45
		S_trnch_10	0.55	Peri_t_1	0.55			Well_10	0.44	S_trnch_3	0.11	S_trnch_1	0.56
		S_trnch_11	0.70	Peri_t_1	0.54			Well_11	0.74	S_trnch_4	0.14	S_trnch_1	0.72
		S_trnch_12	0.56	Peri_t_1	0.43			Well_12	0.41	S_trnch_5	0.18	S_trnch_1	0.58
		S_trnch_13	0.58	Peri_t_1	0.59					S_trnch_6	0.19	S_trnch_1	0.60
		S_trnch_14	0.54	Peri_t_1	1.74					S_trnch_7	0.26	S_trnch_1	0.57
		S_trnch_15	0.52	Peri_t_1	1.22					S_trnch_8	0.35	S_trnch_1	0.55
		S_trnch_16	0.54	Peri_t_1	1.17					S_trnch_9	0.45	S_trnch_1	0.55
		S_trnch_17	0.60	Peri_t_1	1.11					S_trnch_1	0.57	S_trnch_1	0.60
		S_trnch_18	0.60	Peri_t_1	1.02					S_trnch_1	0.72	S_trnch_1	0.65
		S_trnch_19	0.78	Peri_t_1	1.16					S_trnch_1	0.58	S_trnch_1	0.82
		S_trnch_20	2.00	Peri_t_2	0.70					S_trnch_1	0.61	S_trnch_2	2.11
				Peri_t_2	0.66					S_trnch_1	0.57	Peri_RW-1	2.27
				Peri_t_2	0.65					S_trnch_1	0.55	Peri_RW_	8.31
				Peri_t_2	0.63					S_trnch_1	0.56	Peri_RW_	4.09
				Peri_t_2	0.61					S_trnch_1	0.60	Peri_RW_	2.31
				Peri_t_2	0.84					S_trnch_1	0.66	Peri_RW_	2.36
				Peri_t_2	0.00					S_trnch_1	0.82	Peri_RW_	2.75
				Peri_t_2	0.20					S_trnch_2	2.12	Peri_RW_	0.38
				Peri_t_2	0.21							Well_1	0.04
				Peri_t_2	0.54							Well_2	0.03
				Peri_t_3	0.41							Well_3	0.01
				Peri_t_3	0.52							Well_4	0.17
				Peri_t_3	0.14							Well_5	0.83
				Peri_t_3	0.26							Well_6	1.32
				Peri_t_3	0.28							Well_7	1.00
				Peri_t_3	0.29							Well_8	0.51
				Peri_t_3	0.28							Well_9	0.18
				Peri_t_3	0.28							Well_10	0.09
				Peri_t_3	0.36							Well_11	0.09
				Peri_t_3	0.26							Well_12	0.00
				Peri_t_4	0.28								
				Peri_t_4	0.28								
				Peri_t_4	0.29								
				Peri_t_4	0.28								
				Peri_t_4	0.24								
				Peri_t_4	0.21								
				Peri_t_4	0.16								
				Peri_t_4	0.44								
				Peri_t_4	0.28								
				Peri_t_4	0.15								
				Peri_t_5	0.46								
				Peri_t_5	0.32								
				Peri_t_5	0.28								
				Peri_t_5	0.25								
				Peri_t_5	0.21								
				Peri_t_5	0.25								
				Peri_t_5	0.13								
				Peri_t_5	0.11								
				Peri_t_5	0.09								
				Peri_t_5	0.07								
				Peri_t_6	0.14								
				Peri_t_6	0.10								
Well Losses	0.09		9.77		25.36		24.14		20.17		36.40		36.90
Decay Losses	68.08		59.11		45.89		46.98		51.09		35.59		35.35
Total Losses	68.17		68.88		71.25		71.11		71.25		72.00		72.24
% removed	91.45%		92.41%		95.59%		95.40%		95.59%		96.59%		96.92%
% remaining	8.55%		7.59%		4.41%		4.60%		4.41%		3.41%		3.08%

7.2.2.2 Time to Attain MCLs for PCE, TCE, DCE, and VC Concentrations

Figures 7-38 through 7-42 provide useful information regarding the size of the simulated solvent plumes for a 30-year period. However, because the data is at 5-year increments, the time to reach the MCL for each compound cannot be accurately estimated. In cases with slightly higher than MCLs within limited cell locations, concentration contours might not be shown in the 5-year interval plots. In order to provide accurate estimates for these times, Figures 7-43 through 7-44 have been created. These figures show the change in the maximum concentration of each compound for each plume over time. The time at which the maximum concentration has dropped below its MCL is represented by the intercept of the data line and the concentration line representing the MCL. These times are summarized in Tables 7-7 and 7-8.

Compared to ambient conditions, the times to reach the MCLs for simulated pumping conditions at Plume D are reduced from 26 years to 21 years for PCE, from 28 years to 23 years for TCE, from 13.5 years to less than 1 year for DCE, and from 26 years to 19 years for VC. At Plumes H and J, there are only less than 2-year differences between ambient and pumping conditions regarding to the MCL reaching times.

Table 7-7
Time (years) for the Maximum Concentration to Reach the MCLs under Ambient Conditions

Plume	PCE	TCE	DCE	VC
D	26	28	13.5	26
H	-	6.5	<1	<1
J	6.5	<1	<1	2.5

Table 7-8
Time (years) for the Maximum Concentration to Reach the MCLs under Pumping Conditions

Plume	PCE	TCE	DCE	VC
D	21	22.5	<1	19
H	-	5	<1	<1
J	5	<1	<1	2

7.2.2.3 Cumulative Mass Balance for Total Solvents

Figure 7-45 shows the total mass removal of contaminants over 30 years for ambient and pumping conditions. The total mass removal is calculated by summing the total mass removed by the wells and the mass of VC lost to biodegradation. The cumulative mass removal does not reach 100% because approximately 10% of the mass in the initial plume does not move through the Plumes D-H-J model domain. Initial 5 years, pumping

removes more contaminant mass than under ambient conditions. After 20 years, pumping removes less than 50% mass than ambient conditions.

Figure 7-46 shows the mass removal caused by the extraction of contaminants over 30 years under pumping conditions. Significant mass removal occurs in the first 5 years, with more than one-third contaminant mass being removed. Figure 7-47 shows the mass removal caused by naturally-occurring biodegradation for both ambient and pumping conditions. After 30-years, the total mass removed by naturally-occurring biodegradation is about 10 kg for ambient and less than 16 kg for pumping.

Figure 5-48 shows the relevant importance of pumping from well and biodegradation for removing contaminant mass. The contribution of biodegradation to total mass removal increases over time but approaches an asymptotic value after 22 years. After 30 years, the percentage of mass removed by biodegradation as a ratio of mass removed by well pumpage is about 31%.

Tables 7-9 and 7-10 present a summary of the total mass removed by each well for the pumping for 5 and 30 years. The tables show that for pumping condition, the mass removal among the wells spans more than two orders of magnitude. As should be expected, Well No. RW-D2 has removed more than 50% of total mass because the well is located next to a high PCE and TCE well point.

Table 7-9
Summary of Mass (Kg) Removed after 5 Years of Simulation

	Baseline		Extraction Wells	
	MP-1	0.00	RW-D1	1.19
	MP_2	0.00	RW-D2	3.54
	MP_3	0.00	RW-D3	0.57
	S8_4	0.00	RW_D4	0.32
	S8_5	0.00	RW_J1	0.00
	S8_6	0.00	RW_J2	0.01
			RW_J3	0.02
			RW_J4	0.04
			RW_J5	0.00
			RW_J6	0.02
			RW_J7	0.04
			RW_J8	0.09
			RW_J9	0.06
			RW_J10	0.09
			RW_J11	0.07
			RW_J12	0.05
			RW_J13	0.17
			RW_H1	0.07
			RW-H2	0.07
			RW_H3	0.06
			RW_H4	0.09
			RW_H5	0.06
			RW_H6	0.06
			RW_H7	0.06
			RW_H8	0.01
Well Losses		0.00		6.77
Decay Losses		0.81		0.44
Total Losses		0.81		7.21
% removed		4%		34%
% remaining		96%		66%

Table 7-10
Summary of Mass (Kg) Removed after 30 Years of Simulation

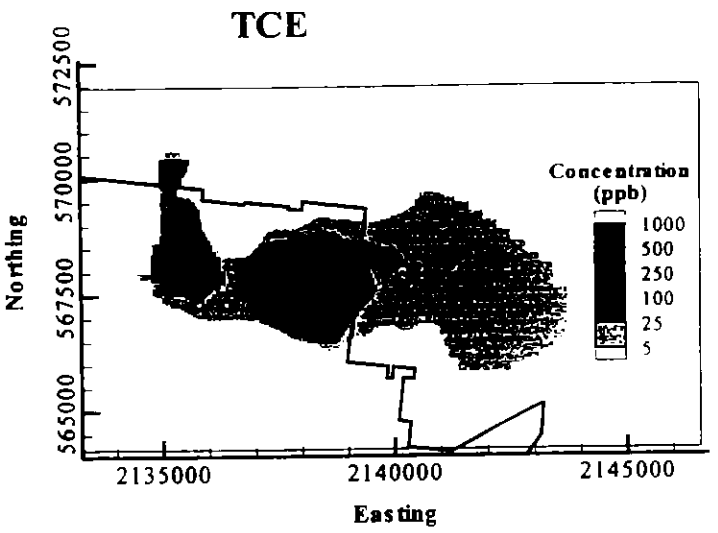
	Baseline		Extraction Wells	
	MP-1	0.12	RW-D1	1.35
	MP_2	0.06	RW-D2	6.00
	MP_3	0.00	RW-D3	1.37
	S8_4	0.00	RW_D4	0.41
	S8_5	0.00	RW_J1	0.00
	S8_6	0.00	RW_J2	0.01
			RW_J3	0.02
			RW_J4	0.04
			RW_J5	0.01
			RW_J6	0.04
			RW_J7	0.06
			RW_J8	0.10
			RW_J9	0.07
			RW_J10	0.11
			RW_J11	0.09
			RW_J12	0.06
			RW_J13	0.21
			RW_H1	0.23
			RW-H2	0.24
			RW_H3	0.22
			RW_H4	0.18
			RW_H5	0.08
			RW_H6	0.08
			RW_H7	0.08
			RW_H8	0.01
Well Losses		0.19		11.04
Decay Losses		10.43		3.75
Total Losses		10.62		14.80
% removed		50%		70%
% remaining		50%		30%

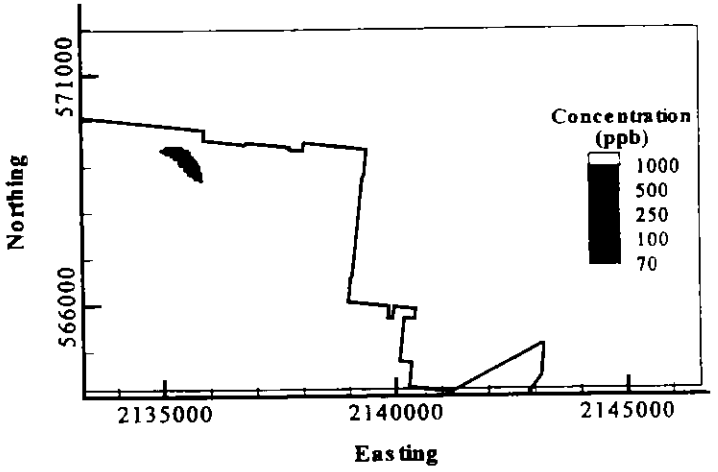
7.3 SUMMARY

Simulated results for ambient baseline and various extraction systems based on flow and transport zoom models can be used to help evaluate remediation alternatives for Zone 5 plumes. For Plume A, the source-area trench and perimeter well extraction system have about 20 years of the MCL reaching time for both on-base and off-base portions of the

plume The addition of the off-base wells to the system does not change the total mass removal rates and MCL reaching times. Particularly, the source-area trench and perimeter well system can contain more contaminant mass within the base boundary, because there is no competing force from the off-base wells.

For Plumes H and J, due to low concentrations, the MCLs for PCE, TCE, and VC can be achieved within two to seven years either for ambient or pumping conditions. For Plume D, the simulated pumping has reduced MCL reaching times for PCE, TCE, and VC from closed to 30 years under ambient conditions to 19 to 23 year range. The maximum mass removal occurs for the well simulated next to the hot-spot well point. Under pumping conditions, the mass removal curve approximates an exponential function with the curve becoming asympotic to a maximum value after about 25 years. Significant mass removing occurs in the first 5 years, with more than one-third contaminant mass being removed.





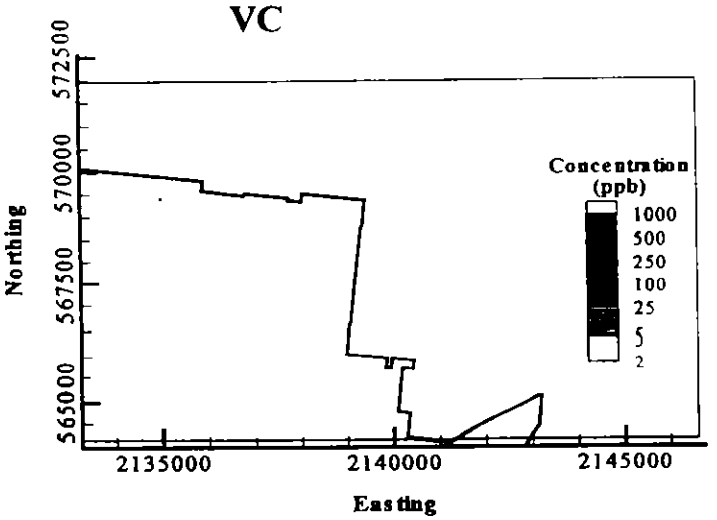


Figure 7-1 Initial Concentration Contours for the Plume A Transport Simulation

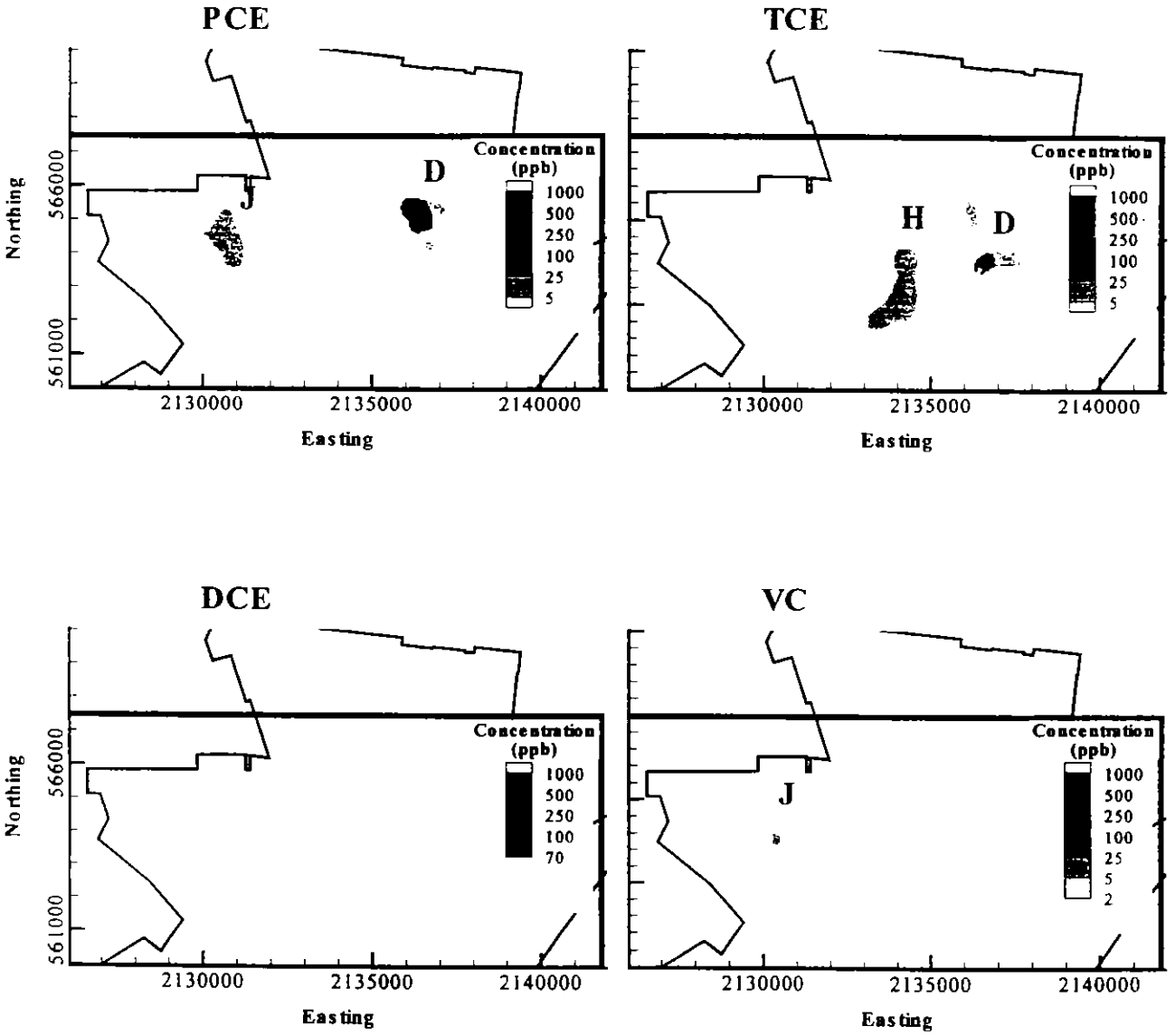


Figure 7-2 Initial Concentration Contours for the Plumes D-H-J Transport Simulation

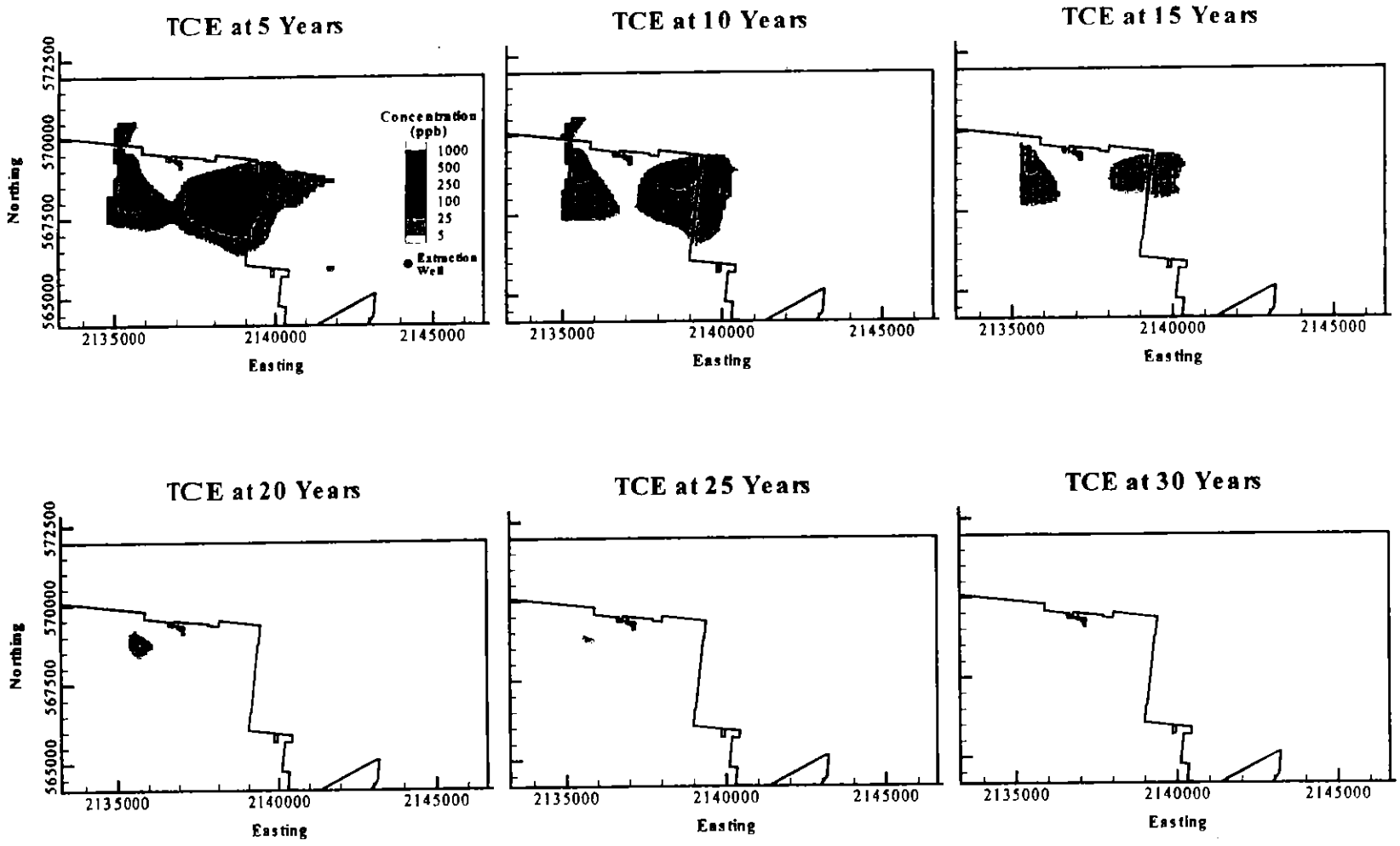


Figure 7-3 Simulated TCE Concentrations for Plume A under Ambient Conditions

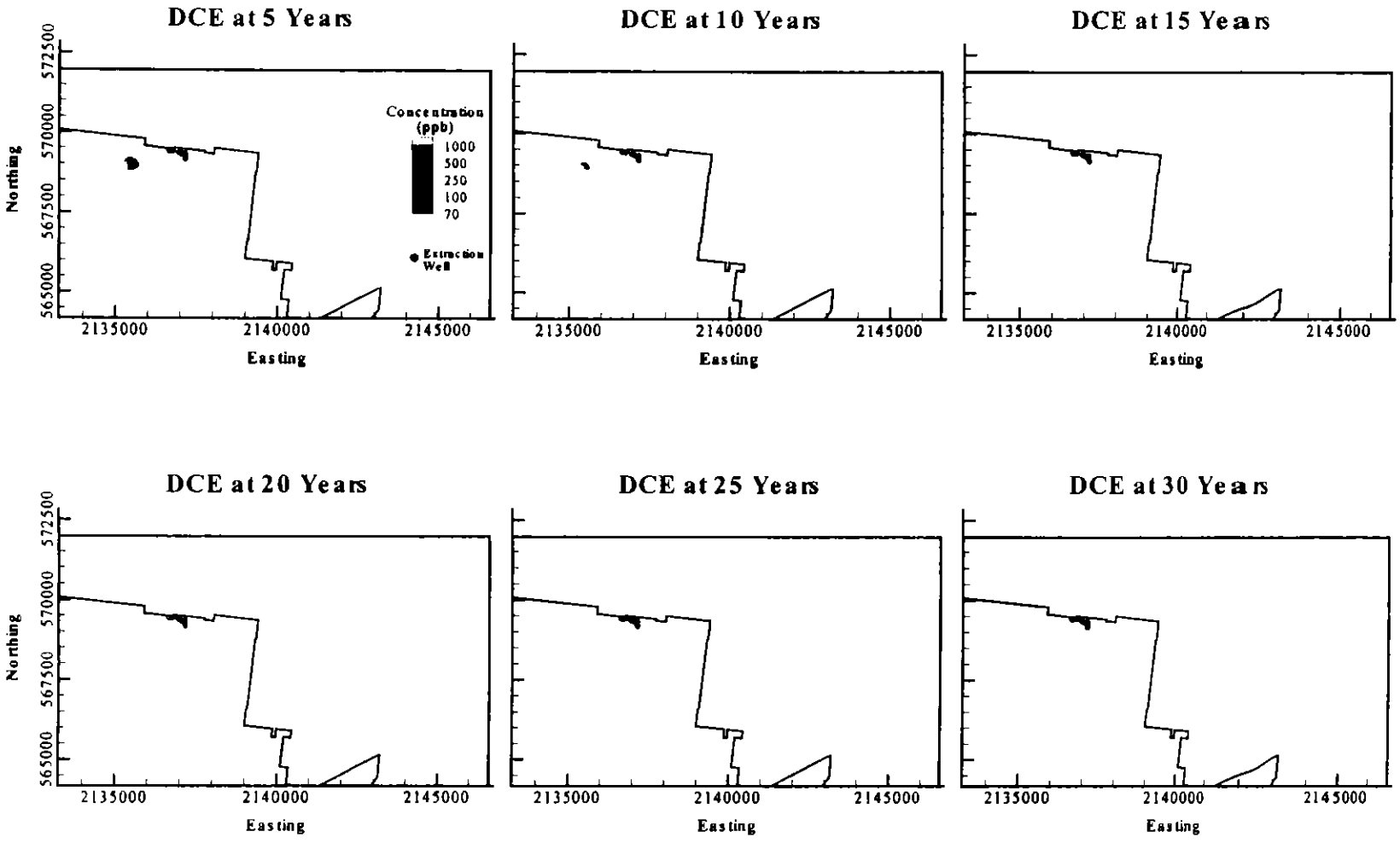


Figure 7-4 Simulated DCE Concentrations for Plume A under Ambient Conditions

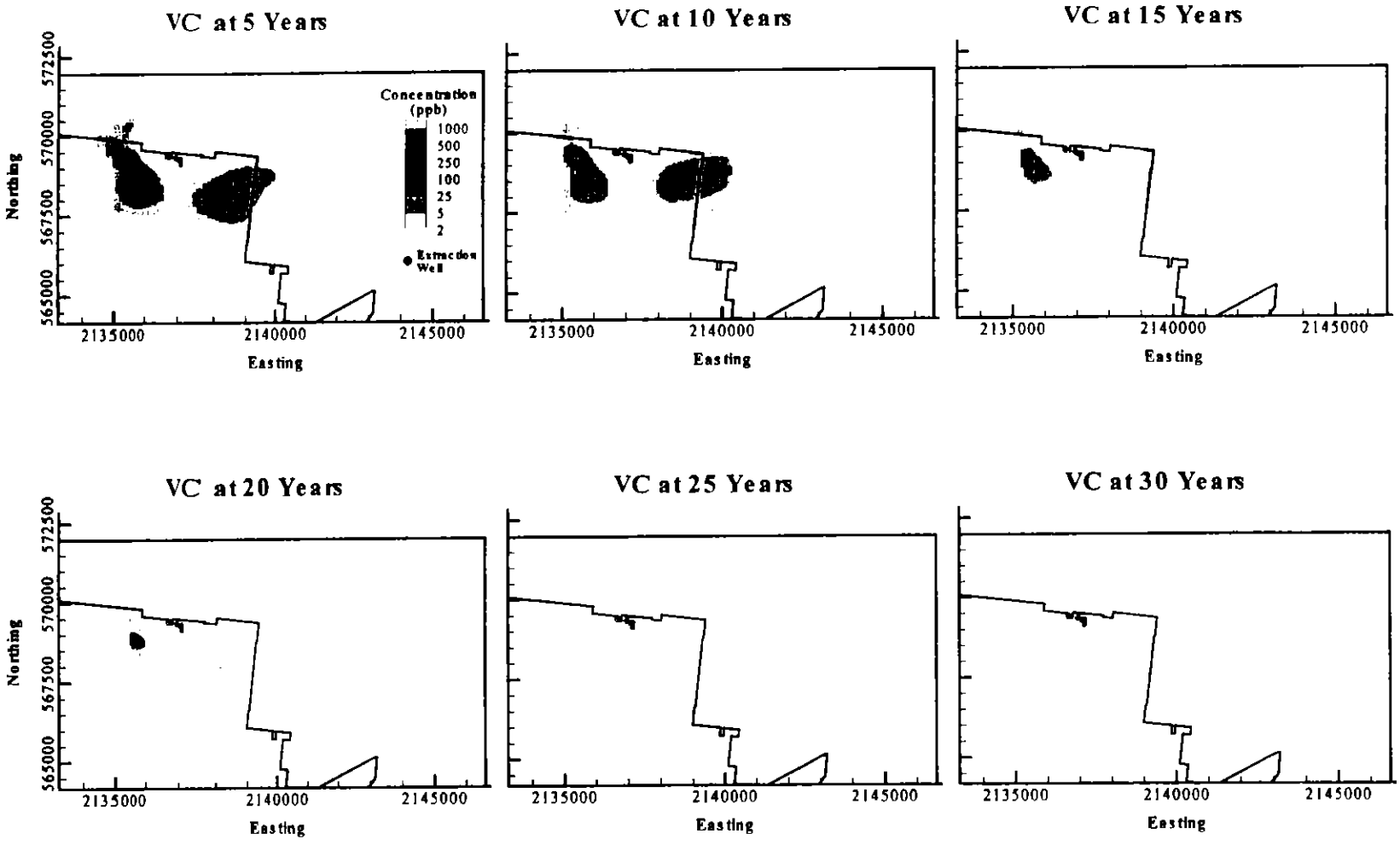


Figure 7-5 Simulated VC Concentrations for Plume A under Ambient Conditions

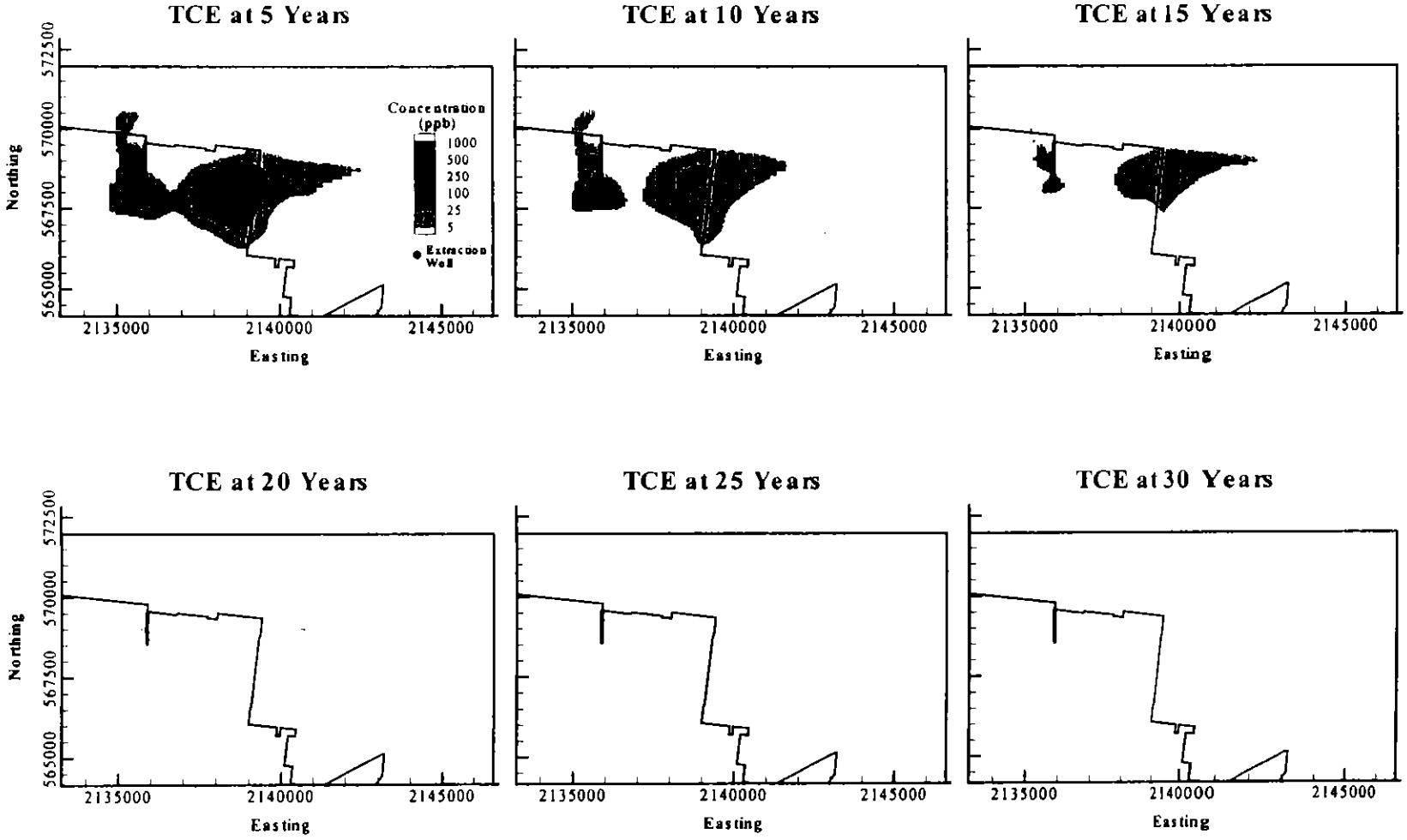


Figure 7-6 Simulated TCE Concentrations for Source-Area Trench Extraction System

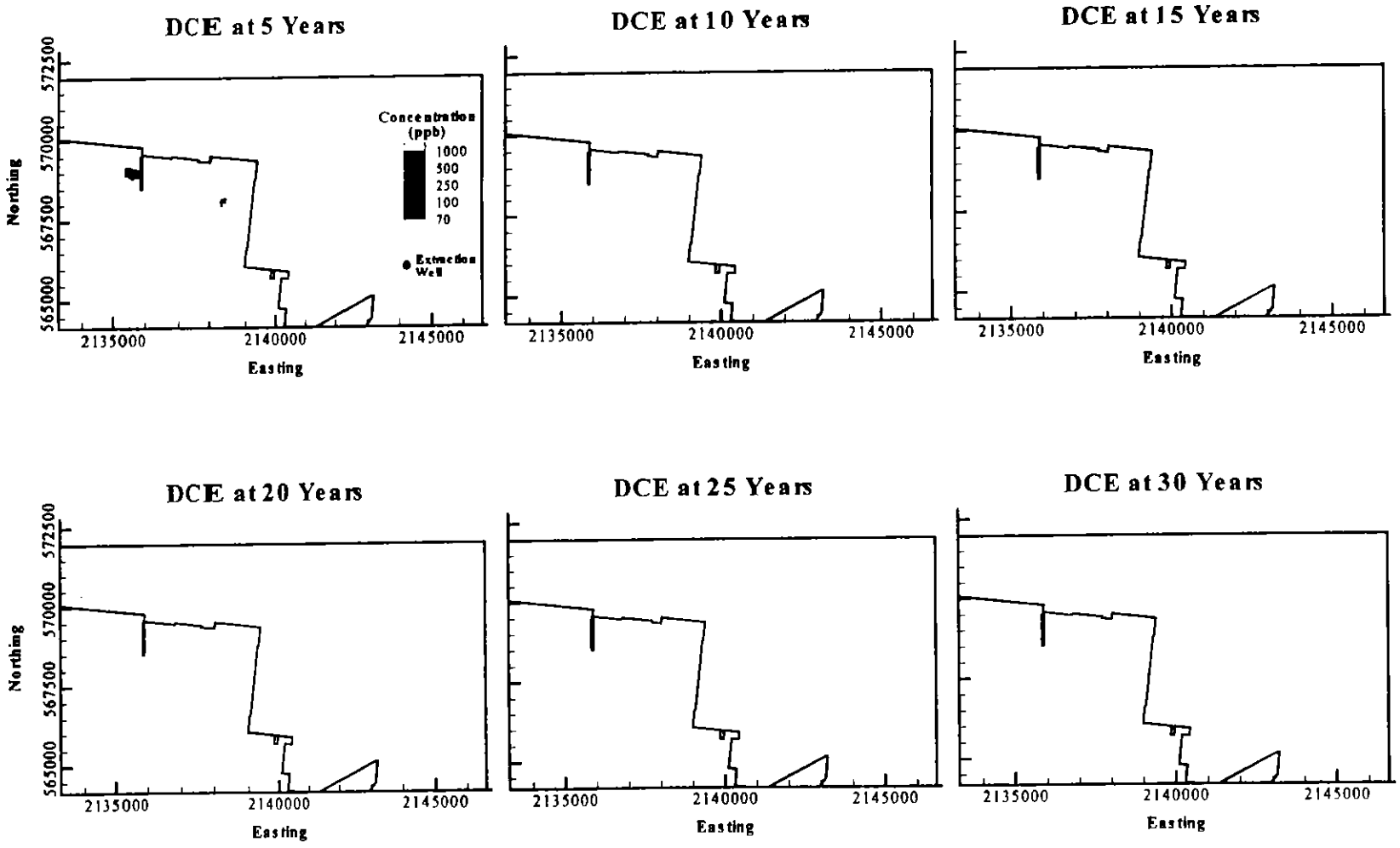


Figure 7-7 Simulated DCE Concentrations for Source-Area Trench Extraction System

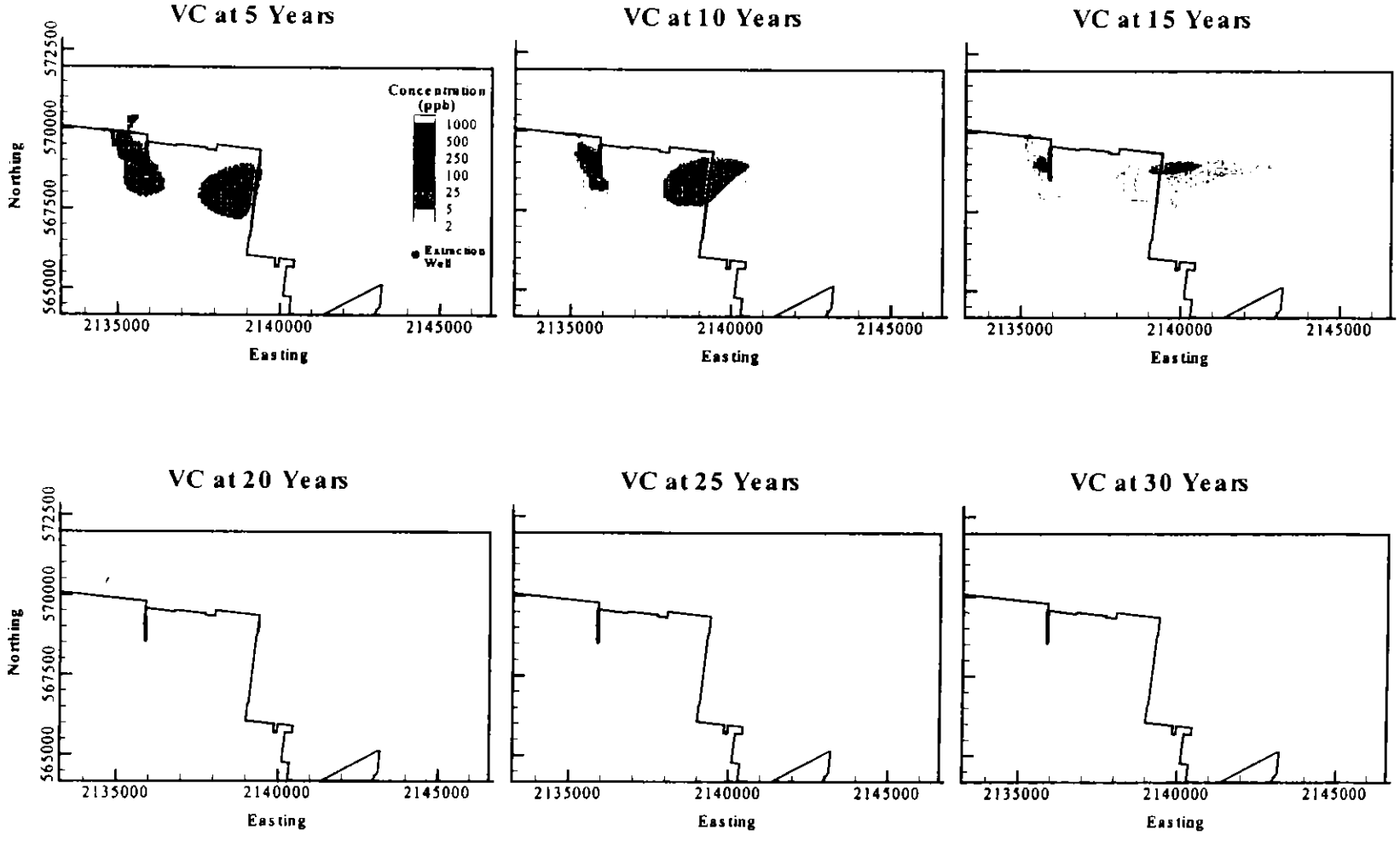


Figure 7-8 Simulated VC Concentrations for Source-Area Trench Extraction System

Appendix H

Groundwater Contaminant Migration Rates

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TABLE H.1
Migration of Selected Contaminants through Groundwater at North Study Area
Kelly AFB, San Antonio, Texas

Contaminant	S-1 Area Velocity (ft/day)	Off Base NE Area Velocity (ft/day)
Benzene	0.65 - 3.00	0.76 - 3.49
Chlorobenzene	0.18 - 1.37	0.21 - 1.59
Dichloroethene, 1,1-	0.81 - 3.29	0.94 - 3.82
Dichloroethene, 1,2-	0.87 - 3.40	1.01 - 3.94
Ethylbenzene	0.06 - 0.51	0.07 - 0.59
Methylphenol, 4-	0.17 - 1.29	0.19 - 1.49
Tetrachloroethene (PCE)	0.17 - 1.28	0.19 - 1.48
Toluene	0.20 - 1.47	0.23 - 1.71
Trichloroethylene (TCE)	0.45 - 2.49	0.52 - 2.89
Xylenes	0.25 - 1.71	0.29 - 1.99
Benzo(a)pyrene	1.14E-05 - 1.14E-04	1.32E-05 - 1.32E-04
Benzo(b)fluoranthene	1.14E-04 - 1.14E-03	1.32E-04 - 1.32E-03
Chrysene	3.12E-04 - 3.12E-03	3.62E-04 - 3.62E-03
Fluoranthene	1.64E-03 - 1.64E-02	1.91E-03 - 1.90E-02
Phenol	2.34 - 4.49	2.72 - 5.21
Pyrene	1.64E-03 - 1.64E-02	1.91E-03 - 1.90E-02
PCB 1260	1.18E-04 - 1.18E-03	1.37E-04 - 1.37E-03
Chlordane-alpha	1.43E-03 - 1.43E-02	1.66E-03 - 1.66E-02
Chlordane-gamma	4.46E-04 - 4.46E-03	5.18E-04 - 5.17E-03
DDE	1.42E-05 - 1.42E-04	1.65E-05 - 1.65E-04
DDT	2.57E-04 - 2.57E-03	2.98E-04 - 2.98E-03
Arsenic	2.98E-04 - 2.97E-03	3.45E-04 - 3.45E-03
Barium	4.17E-04 - 4.16E-03	4.83E-04 - 4.83E-03
Cadmium	6.94E-05 - 6.94E-04	8.06E-05 - 8.05E-04
Cobalt	2.16E-04 - 2.15E-03	2.50E-04 - 2.50E-03
Copper	1.00E-05 - 1.00E-04	1.17E-05 - 1.17E-04
Cyanide	6.25E-04 - 6.24E-03	7.25E-04 - 7.24E-03
Nickel	1.69E-04 - 1.69E-03	1.96E-04 - 1.96E-03
Vanadium	1.04E-03 - 1.04E-02	1.21E-03 - 1.21E-02

TABLE H.2
Calculation of Groundwater Migration Velocities at South Study Area
Kelly AFB, San Antonio, Texas

Contaminant	Mid-Runway Velocity (ft/day)	South Runway Velocity (ft/day)
Dichloroethane, 1,1-	1.91 - 5.24	1.00 - 2.74
Dichloroethene (total), 1,2-	1.14 - 4.42	0.59 - 2.31
Ethylbenzene	0.07 - 0.66	0.04 - 0.35
Tetrachloroethene (PCE)	0.22 - 1.66	0.11 - 0.87
Toluene	0.26 - 1.91	0.14 - 1.00
Trichloroethylene (TCE)	0.59 - 3.24	0.31 - 1.69
Vinyl chloride	1.17 - 4.46	0.61 - 2.34
Xylenes (total)	0.32 - 2.23	0.17 - 1.16
Benzo(a)anthracene	5.89E-05 - 5.89E-04	3.08E-05 - 3.08E-04
Benzo(a)pyrene	1.48E-05 - 1.48E-04	7.73E-06 - 7.73E-05
Benzo(b)fluoranthene	1.48E-04 - 1.48E-03	7.73E-05 - 7.73E-04
Benzo(g,h,i)perylene	5.08E-05 - 5.08E-04	2.66E-05 - 2.66E-04
Benzo(k)fluoranthene	1.48E-04 - 1.48E-03	7.73E-05 - 7.73E-04
Fluoranthene	2.14E-03 - 2.13E-02	1.12E-03 - 1.11E-02
Indeno(1,2,3-cd)pyrene	5.08E-05 - 5.08E-04	2.66E-05 - 2.66E-04
Phenanthrene	5.80E-03 - 5.75E-02	3.03E-03 - 3.01E-02
Pyrene	2.14E-03 - 2.13E-02	1.12E-03 - 1.11E-02
DDE	1.85E-05 - 1.85E-04	9.66E-06 - 9.66E-05
DDT	3.34E-04 - 3.34E-03	1.75E-04 - 1.75E-03
Arsenic	3.87E-04 - 3.87E-03	2.02E-04 - 2.02E-03
Cadmium	9.03E-05 - 9.03E-04	4.72E-05 - 4.72E-04
Chromium	8.12E-04 - 8.11E-03	4.25E-04 - 4.24E-03
Cobalt	2.80E-04 - 2.80E-03	1.47E-04 - 1.46E-03
Cyanide	8.12E-04 - 8.11E-03	4.25E-04 - 4.24E-03
Mercury	2.54E-04 - 2.54E-03	1.33E-04 - 1.33E-03
Nickel	2.20E-04 - 2.20E-03	1.15E-04 - 1.15E-03
Vanadium	1.35E-03 - 1.35E-02	7.08E-04 - 7.07E-03

TABLE H.3
Migration of Selected Contaminants Through Groundwater at West Study Area
Kelly AFB, San Antonio, Texas

Contaminant	149th TANG Velocity (ft/day)	1100 Area Velocity (ft/day)
Benzene	0.07 - 0.31	0.21 - 0.96
Chlorobenzene	0.02 - 0.14	0.06 - 0.44
Dichlorobenzene, 1,2-	0.06 - 0.29	0.18 - 0.89
Dichlorobenzene, 1,3-	0.05 - 0.26	0.15 - 0.80
Dichlorobenzene, 1,4-	0.07 - 0.32	0.22 - 0.97
Dichloroethane, 1,1-	0.15 - 0.42	0.47 - 1.29
Dichloroethene, 1,1-	0.08 - 0.34	0.26 - 1.05
Dichloroethene (total), 1,2-	0.09 - 0.35	0.28 - 1.08
Ethylbenzene	0.01 - 0.05	0.02 - 0.16
2-Methylnaphthalene	0.001 - 0.01	0.002 - 0.02
Tetrachloroethene (PCE)	0.02 - 0.13	0.05 - 0.41
Toluene	0.02 - 0.15	0.06 - 0.47
Trichloroethylene (TCE)	0.05 - 0.26	0.14 - 0.79
Vinyl chloride	0.09 - 0.36	0.29 - 1.10
Xylenes (total)	0.03 - 0.18	0.08 - 0.55
Acenaphthene	1.41E-03 - 1.38E-02	4.33E-03 - 4.22E-02
Acenaphthylene	2.59E-03 - 2.48E-02	7.94E-03 - 7.60E-02
Anthracene	4.64E-04 - 4.60E-03	1.42E-03 - 1.41E-02
Benzo(a)anthracene	4.71E-06 - 4.71E-05	1.45E-05 - 1.45E-04
Benzo(a)pyrene	1.18E-06 - 1.18E-05	3.63E-06 - 3.63E-05
Benzo(b)fluoranthene	1.18E-05 - 1.18E-04	3.63E-05 - 3.63E-04
Benzo(g,h,i)perylene	4.06E-06 - 4.06E-05	1.25E-05 - 1.25E-04
Benzo(k)fluoranthene	1.18E-05 - 1.18E-04	3.63E-05 - 3.63E-04
Carbazole	3.47E-02 - 2.17E-01	1.06E-01 - 6.65E-01
Chrysene	3.25E-05 - 3.25E-04	9.97E-05 - 9.97E-04
Dibenzo(a,h)anthracene	1.97E-06 - 1.97E-05	6.05E-06 - 6.05E-05
Fluoranthene	1.71E-04 - 1.70E-03	5.25E-04 - 5.23E-03
Fluorene	8.89E-04 - 8.75E-03	2.73E-03 - 2.69E-02
Phenanthrene	4.64E-04 - 4.60E-03	1.42E-03 - 1.41E-02
Pyrene	1.71E-04 - 1.70E-03	5.25E-04 - 5.23E-03
Phenanthrene	4.64E-04 - 4.60E-03	1.42E-03 - 1.41E-02
Dibenzofuran	1.91E-05 - 1.91E-04	5.87E-05 - 5.87E-04
DDE	7.65E-06 - 7.65E-05	2.35E-05 - 2.35E-04
DDT	2.71E-07 - 2.71E-06	8.31E-07 - 8.31E-06
Arsenic	3.10E-05 - 3.09E-04	9.50E-05 - 9.49E-04
Barium	4.33E-05 - 4.33E-04	1.33E-04 - 1.33E-03
Beryllium	5.65E-06 - 5.65E-05	1.73E-05 - 1.73E-04
Cadmium	7.22E-06 - 7.22E-05	2.22E-05 - 2.22E-04
Cobalt	2.24E-05 - 2.24E-04	6.88E-05 - 6.88E-04
Nickel	1.76E-05 - 1.76E-04	5.39E-05 - 5.39E-04

TABLE H.4
Migration of Selected Contaminants through Groundwater at East Study Area
Kelly AFB, San Antonio, Texas

Contaminant	CE MotorPool Velocity (ft/day)	Base Service Station Velocity (ft/day)	Duncan Velocity (ft/day)	S-5 / S-10 Velocity (ft/day)
Benzene	1.73E-01 - 9.52E-01	2.92E-01 - 1.60E+00	6.84E-02 - 3.76E-01	1.92E-02 - 1.05E-01
Butylbenzene, sec-	1.76E-02 - 1.63E-01	2.97E-02 - 2.74E-01	6.95E-03 - 6.41E-02	1.95E-03 - 1.80E-02
Butylbenzene, t-	2.31E-02 - 2.09E-01	3.90E-02 - 3.51E-01	9.13E-03 - 8.23E-02	2.56E-03 - 2.30E-02
Chloroethane	6.81E-01 - 1.61E+00	1.15E+00 - 2.71E+00	2.69E-01 - 6.36E-01	7.53E-02 - 1.78E-01
Dichloroethane, 1,1-	4.13E-01 - 1.40E+00	6.96E-01 - 2.35E+00	1.63E-01 - 5.51E-01	4.57E-02 - 1.54E-01
Dichloroethene, 1,1-	2.16E-01 - 1.07E+00	3.64E-01 - 1.80E+00	8.52E-02 - 4.21E-01	2.39E-02 - 1.18E-01
Dichloroethene (total), 1,2-	2.35E-01 - 1.11E+00	3.96E-01 - 1.87E+00	9.28E-02 - 4.39E-01	2.60E-02 - 1.23E-01
Ethylbenzene	1.43E-02 - 1.34E-01	2.41E-02 - 2.25E-01	5.64E-03 - 5.28E-02	1.58E-03 - 1.48E-02
Isopropylbenzene	5.60E-03 - 5.46E-02	9.44E-03 - 9.19E-02	2.21E-03 - 2.15E-02	6.19E-04 - 6.03E-03
2-Methylnaphthalene	1.86E-03 - 1.84E-02	3.13E-03 - 3.11E-02	7.35E-04 - 7.28E-03	2.06E-04 - 2.04E-03
Propylbenzene, n-	2.11E-02 - 1.92E-01	3.56E-02 - 3.23E-01	8.34E-03 - 7.58E-02	2.34E-03 - 2.12E-02
Trichloroethane, 1,1,1-	9.88E-02 - 6.73E-01	1.66E-01 - 1.13E+00	3.90E-02 - 2.66E-01	1.09E-02 - 7.44E-02
Tetrachloroethene (PCE)	4.25E-02 - 3.54E-01	7.16E-02 - 5.96E-01	1.68E-02 - 1.40E-01	4.70E-03 - 3.91E-02
Toluene	5.14E-02 - 4.13E-01	8.65E-02 - 6.96E-01	2.03E-02 - 1.63E-01	5.68E-03 - 4.57E-02
Trichloroethylene (TCE)	1.18E-01 - 7.56E-01	1.99E-01 - 1.27E+00	4.65E-02 - 2.99E-01	1.30E-02 - 8.36E-02
Xylenes (total)	6.38E-02 - 4.90E-01	1.07E-01 - 8.25E-01	2.52E-02 - 1.93E-01	7.05E-03 - 5.41E-02
Anthracene	1.13E-03 - 1.12E-02	1.90E-03 - 1.89E-02	4.46E-04 - 4.44E-03	1.25E-04 - 1.24E-03
Benzo(a)anthracene	1.15E-05 - 1.15E-04	1.93E-05 - 1.93E-04	4.53E-06 - 4.53E-05	1.27E-06 - 1.27E-05
Benzo(a)pyrene	2.88E-06 - 2.88E-05	4.85E-06 - 4.85E-05	1.14E-06 - 1.14E-05	3.18E-07 - 3.18E-06
Benzo(b)fluoranthene	2.88E-05 - 2.88E-04	4.85E-05 - 4.85E-04	1.14E-05 - 1.14E-04	3.18E-06 - 3.18E-05
Benzo(g,h,i)perylene	9.90E-06 - 9.90E-05	1.67E-05 - 1.67E-04	3.91E-06 - 3.91E-05	1.09E-06 - 1.09E-05
Benzo(k)fluoranthene	2.88E-05 - 2.88E-04	4.85E-05 - 4.85E-04	1.14E-05 - 1.14E-04	3.18E-06 - 3.18E-05
Carbazole	8.64E-02 - 6.13E-01	1.45E-01 - 1.03E+00	3.41E-02 - 2.42E-01	9.55E-03 - 6.77E-02
Chrysene	7.92E-05 - 7.91E-04	1.33E-04 - 1.33E-03	3.12E-05 - 3.12E-04	8.75E-06 - 8.75E-05
Dibenzo(a,h)anthracene	4.80E-06 - 4.80E-05	8.08E-06 - 8.08E-05	3.66E-03 - 3.50E-02	1.02E-03 - 9.81E-03
Fluoranthene	4.17E-04 - 4.16E-03	7.02E-04 - 7.00E-03	1.89E-06 - 1.89E-05	5.30E-07 - 5.30E-06
Fluorene	2.17E-03 - 2.14E-02	3.65E-03 - 3.61E-02	1.64E-04 - 1.64E-03	4.60E-05 - 4.60E-04
Indeno(1,2,3-cd)pyrene	9.90E-06 - 9.90E-05	1.67E-05 - 1.67E-04	8.55E-04 - 8.47E-03	2.39E-04 - 2.37E-03
Naphthalene	1.80E-02 - 1.66E-01	3.03E-02 - 2.79E-01	3.91E-06 - 3.91E-05	1.09E-06 - 1.09E-05
Phenanthrene	1.13E-03 - 1.12E-02	1.90E-03 - 1.89E-02	7.11E-03 - 6.55E-02	1.99E-03 - 1.83E-02
Pyrene	1.13E-03 - 1.12E-02	1.90E-03 - 1.89E-02	4.46E-04 - 4.44E-03	1.25E-04 - 1.24E-03
Dieldrin	9.27E-03 - 8.88E-02	1.56E-02 - 1.50E-01	3.66E-03 - 3.50E-02	1.25E-04 - 1.24E-03
DDE	3.60E-06 - 3.60E-05	6.06E-06 - 6.06E-05	1.42E-06 - 1.42E-05	3.98E-07 - 3.98E-06
Arsenic	1.13E-04 - 1.13E-03	1.90E-04 - 1.90E-03	4.46E-05 - 4.46E-04	1.25E-05 - 1.25E-04
Barium	1.58E-04 - 1.58E-03	2.67E-04 - 2.66E-03	6.25E-05 - 6.24E-04	1.75E-05 - 1.75E-04
Beryllium	2.07E-05 - 2.06E-04	3.48E-05 - 3.48E-04	8.15E-06 - 8.15E-05	2.28E-06 - 2.28E-05
Cadmium	2.64E-05 - 2.64E-04	4.44E-05 - 4.44E-04	1.04E-05 - 1.04E-04	2.92E-06 - 2.92E-05
Cobalt	8.19E-05 - 8.19E-04	1.38E-04 - 1.38E-03	3.23E-05 - 3.23E-04	9.05E-06 - 9.05E-05
Nickel	6.42E-05 - 6.42E-04	1.08E-04 - 1.08E-03	2.53E-05 - 2.53E-04	7.09E-06 - 7.09E-05

Appendix I

Kelly AFB Zone 5 Air Stripping Preliminary Air Quality Regulatory Review

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MEMORANDUM CH2MHILL

Kelly AFB Zone 5 Air Stripping Preliminary Air Quality Regulatory Review

TO: Lida McAllister/CH2M HILL

COPIES: Linda Johnson/CH2M HILL
John Ludowise/CH2M HILL
Charles Hedel/CH2M HILL

FROM: Julian Laurenz/CH2M HILL

DATE: November 13, 1998

The purpose of this memorandum is to document the exemption from emission controls and permitting of the plans to implement an air stripping system for remediation of the groundwater at Kelly Air Force Base Zone 5. The exemption is based on the estimated quantity of contaminants of concern in the groundwater.

The exemptions for air pollution control permitting are outlined in Chapter 106 of the Texas Natural Resource Conservation Commission (TNRCC) rules. Water and soil remediation projects which meet seven specific conditions are exempt under Chapter 106.533. Five of the seven conditions can be met without analysis. Two of the conditions require an estimate of the hourly emission rate of total petroleum hydrocarbons (TPH) and of specific chemical emissions for non-TPH compounds. The following compounds applicable to Zone 5 and the corresponding emission rate exemption level are evaluated in this memorandum:

Pollutant	Exemption Level (lb/hr)[1]
Chlorobenzene (CB)	1.0
1,2-dichloroethylene (1,2-DCE)	0.242
Trichloroethylene (TCE)	0.414
Perchloroethylene (PCE)	0.103

[1] This value is calculated assuming D, the distance to the nearest off site receptor, is equal to 100 ft in the equation listed in 106.262 (3).

For purposes of evaluating different remediation options, the Draft Zone 5 Corrective Measures Study is divided into Plumes A-K. Each plume has one, or more, of the contaminants of concern (COC) listed in the table above. The concentration of COCs varies for each plume. One of the options to remediate the COCs in each plume is to install pump and treat systems, with the treatment portion being air strippers. The pumping system consists of a series of wells that extract the COC, with the pumping rate for each set of wells varying.

The hourly emission estimate is based on two items: 1) The highest concentration of COC in a plume, and 2) The highest flowrate that a treatment system processes the COC, which is based on the flowrate extracted from the wells. For example, the highest concentration of

TCE extracted from Plume A is 100 µg/L, and the highest flowrate expected is 100 gpm. The emission estimate (in lb/hr) would be calculated based on these values.

The Draft Zone 5 Corrective Measures Study lists the highest concentrations for each COC, and the largest flowrate expected to be processed. The data are summarized in the table below.

Plume	CB (µg/L)	1,2-DCE (µg/L)	PCE (µg/L)	TCE (µg/L)	Highest Flowrate (gpm)
A	0	10	0	100	100
C (1)	NA	NA	NA	NA	NA
D	0	0	18	100	74
E (2)	NA	NA	NA	NA	NA
F	0	0	0	0	0
G (2)	NA	NA	NA	NA	NA
H	0	4	0	5	160
I	0	71	100	15	40
J	0	0	5	5	100
K	100	0	0	0	30

(1) To be remediated with S-1 treatment system.

(2) To be remediated through the PST program

NA = Not applicable

The hourly emission rates were calculated using the following formula:

Emission Rate (lb/hr) = (maximum concentration) x (highest flowrate) x (conversion factors)

Using TCE from Plume A as an example:

Emission Rate (TCE) = (100 µg/L) x (100 gal/min) x (3.785 L/gal) x (1g/1E+6 µg) x (1 lb/454 g) x (60 min/hr) = 0.005 lb/hr

The remaining hourly emission rates are calculated using the same formula, and the results are summarized on the following table.

Plume	CB (lb/hr)	1,2-DCE (lb/hr)	PCE (lb/hr)	TCE (lb/hr)
A	0	0.0005	0	0.005
C	0	0	0	0
D	0	0	0.00066	0.0037
E	0	0	0	0
F	0	0	0	0
G	0	0	0	0
H	0	0.00032	0	0.0004
I	0	0.0014	0.002	0.0003
J	0	0	0.0002	0.00025
K	0.0015	0	0	0
TOTAL	0.0015	0.0022	0.0029	0.0097

The above estimates are conservative for several reasons: 1) they assume maximum concentrations and flow rates for each COC, 2) they assume the entire mass is removed with no contaminant biodegradation and 3) the hourly emission rate will not decrease as contaminant is removed from groundwater.

All of the estimated emission rates are below the calculated or published exemption level in Chapter 106 of the TNRCC rules, therefore, the planned remediation system is exempt from air pollution control permitting.

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Appendix J

Remedial Alternative Costing for Groundwater Order of Magnitude Comparative Cost Estimating (Accuracy of +50% to –30%)

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UVOX Treatment System

Treatment System Costs

he costs for the system are based on a 400 gallons per minute centralized system. It includes all costs for transfer piping from the individual plumes (see Figure 6.7 of main text), the treatment system, associated foundation, electrical, instrumentation, and piping.
The Operations and Maintenance costs are based on the costs for the transfer piping and Treatment system only.

Costs associated with wells, trenches, extraction piping (from extraction point to transfer pipe header) will be calculated separately.

CAPITAL COSTS

1. Transfer Piping (from extraction piping to treatment system) **$307,944**

HDPE Pipe $307,944

Pipe Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Unit Cost Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
Ext 4	4,800	240	$5.56	$2.61	$41,185
Ext 6	19,200	960	$5.56	$4.92	$211,260
Rtn 3 (c)	14,500	725	$0.00	$1.94	$29,463
Rtn 4 (c)	9,500	475	$0.00	$2.61	$26,036

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor
(c) Extraction and Return pipes in same trench, no cost for excavtion.

2. Treatment System (400 gpm UV/OX) **$893,649**

A. Treatment/Storage/Office Building $72,576

Assume a 40 ft x 40 ft building to house the UV/OX treatment system

Concrete Foundation	59 CY (40ft x 40ft x 1 ft thick)			
Excavation	59 CY at	$3.25	/CY =	$192
Compaction	59 CY at	$2.43	/CY =	$143
Placement	59 CY at	$139.68	/CY =	$8,241

Pre-Engineered Structure 1,600 square ft

Including Building, Insulation, HVAC unit, Electrical, and Lighting.
Assume $40.00 /square ft = $64,000

B. Power to site $28,446

	Materials	Installation	Subtotal
Oil Filled Pad Mounted 112.5 KVA Transformer	$14,069	$426	$14,495
Watt-hour-meter and current transformers	$1,500	$500	$2,000
600A Main Circuit, breaker distribution	$10,451	$1,500	$11,951

C. UV Oxidation Treatment System $787,545

Cost of System Delivered to site (1 - 90 KW)	$194,000
Installation (placing and bolting)	$7,385

UVOX Treatment System

Treatment System Costs

Cost of PLC (including programming)	$365,000
Installation of PLC	$73,000
Influent and Effluent Holding Tanks	$20,000
Assume the cost of each tank installed =	$10,000
2 tanks at $10,000 each =	$20,000
Transfer Pump (from system to EPS)	$8,160
Cost of Pump and Motor =	$6,800
Installation (assumed at 20% of capital)	$1,360
Flow measuring and control devices	$120,000

Assume $100,000 for all valves, piping, duct work, and flow devices
Labor $20,000 (assumed at 20% of capital)

E. Fencing $5,081

Assume UV/OX treatment system enclosed by 100 ft by 100 ft fence with two 12 ft gates

376 linear feet of fence at	$10.28 /lf =	$3,865	
2 12 ft gates at	$608 ea. =	$1,216	

3. Testing **$12,240**

Assume 4 technicians and 2 engineers for 3 weeks to test the system

4 Technicians at	$48 /hr for	3 weeks =	$5,760
2 Engineers at	$54 /hr for	3 weeks =	$6,480

4. Implementation Costs **$449,118**

Assume Implementation costs at 37% of Capital Costs
Includes Permitting and legal, Services During Construction, Health and Safety,
Report preparation, and engineering design costs.

TOTAL CAPITAL COSTS

Subtotal (ST)	**$1,663,000**
Overhead and Profit @ 15.5%	**$258,000**
Mob/Bond/Insur @ 5% of ST	**$83,000**
Contingency @ 10% of ST	**$166,000**
Total	**$2,170,000**

O&M Costs-

1. Electrical Costs **$5,446**

Transfer System:

Assume	10	HP pump (400 GPM system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

Treatment System Costs

2. Treatment System Operation **$304,666**

A. Labor **$212,160**

Assume 2 full time employees annually
Assume tasks to include all system sampling/maintenance, Report writing etc.

Assume	1	engineer @	$54	per hour
Assume	1	technician @	$48	per hour

B. Operations Maintenance **$92,506**

Assume system O&M Costs at $0.44 per 1000 gallons water
400 gpm for 8760 hrs per yr = 210,240,000 gallons per year

3. Treatment System Influent and Effluent Water Monitoring **$18,624**

Assume 4 samples every month (2 per event, 1 effluent and 1 influent)
Data Validation Labor per Sample = $67
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

TOTAL O&M COSTS **$328,735**

PRESENT WORTH CALCULATIONS

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$2,170,000	$0	1.0000	$2,170,000	$2,170,000
1	$0	$328,735	0.9302	$328,735	$305,800
2	$0	$328,735	0.8653	$328,735	$284,465
3	$0	$328,735	0.8050	$328,735	$264,619
4	$0	$328,735	0.7488	$328,735	$246,157
5	$0	$336,895	0.6966	$336,895	$234,667
6	$0	$328,735	0.6480	$328,735	$213,008
7	$0	$328,735	0.6028	$328,735	$198,147
8	$0	$328,735	0.5607	$328,735	$184,323
9	$0	$328,735	0.5216	$328,735	$171,463
10	$0	$336,895	0.4852	$336,895	$163,460
11	$0	$328,735	0.4513	$328,735	$148,372
12	$0	$328,735	0.4199	$328,735	$138,021
13	$0	$328,735	0.3906	$328,735	$128,392
14	$0	$328,735	0.3633	$328,735	$119,434
15	$0	$336,895	0.3380	$336,895	$113,859
16	$0	$328,735	0.3144	$328,735	$103,350
17	$0	$328,735	0.2925	$328,735	$96,140
18	$0	$328,735	0.2720	$328,735	$89,432
19	$0	$328,735	0.2531	$328,735	$83,193
20	$0	$336,895	0.2354	$336,895	$79,310
21	$0	$328,735	0.2190	$328,735	$71,989
22	$0	$328,735	0.2037	$328,735	$66,967
23	$0	$328,735	0.1895	$328,735	$62,295
24	$0	$328,735	0.1763	$328,735	$57,949
25	$0	$336,895	0.1640	$336,895	$55,244
26	$0	$328,735	0.1525	$328,735	$50,145
27	$0	$328,735	0.1419	$328,735	$46,646
28	$0	$328,735	0.1320	$328,735	$43,392
29	$0	$328,735	0.1228	$328,735	$40,365
30	$0	$328,735	0.1142	$328,735	$37,548
	$2,170,000	**$9,902,862**			**$6,068,152**

UVOX Treatment System (400 GPM capacity) ***$6,100,000***

UVOX Treatment System

ALT. 3 - Treatment System Costs

The costs for the system are based on a 138 gallons per minute centralized system. It includes all costs for transfer piping from the individual plumes (see Figure 6.23 of main text), the treatment system, associated foundation, electrical, instrumentation, and piping.
The Operations and Maintenance costs are based on the costs for the transfer piping and Treatment system only.

Costs associated with wells, trenches, extraction piping (from extraction point to transfer pipe header) will be calculated separately.

CAPITAL COSTS

1. Transfer Piping (from extraction piping to treatment system) **$155,194**

HDPE Pipe $155,194

Pipe Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
Ext 2	9,500	475	$4.64	$1.37	$60,002
Ext 4	12,500	625	$4.64	$2.61	$95,192

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

2. Treatment System (138 gpm UV/OX) **$794,649**

A. Treatment/Storage/Office Building **$72,576**

Assume a 40 ft x 40 ft building to house the UV/OX treatment system

Concrete Foundation	59 CY (40ft x 40ft x 1 ft thick)			
Excavation	59 CY at	$3.25	/CY =	$192
Compaction	59 CY at	$2.43	/CY =	$143
Placement	59 CY at	$139.68	/CY =	$8,241

Pre-Engineered Structure 1,600 square ft

Including Building, Insulation, HVAC unit, Electrical, and Lighting.
Assume $40.00 /square ft = $64,000

B. Power to site $28,446

	Materials	Installation	Subtotal
Oil Filled Pad Mounted 112.5 KVA Transformer	$14,069	$426	$14,495
Watt-hour-meter and current transformers	$1,500	$500	$2,000
600A Main Circuit, breaker distribution	$10,451	$1,500	$11,951

C. UV Oxidation Treatment System **$688,545**

Cost of System Delivered to site (1 - 30 KW)	$95,000
Installation (placing and bolting)	$7,385
Cost of PLC (including programming)	$365,000
Installation of PLC	$73,000

ALT. 3 - Treatment System Costs

Influent and Effluent Holding Tanks			$20,000
Assume the cost of each tank installed =			$10,000
2 tanks at	$10,000	each =	$20,000
Transfer Pump (from system to EPS)			$8,160
Cost of Pump and Motor =			$6,800
Installation (assumed at 20% of capital)			$1,360
Flow measuring and control devices			$120,000
Assume	$100,000	for all valves, piping, duct work, and flow devices	
Labor	$20,000	(assumed at 20% of capital)	

E. Fencing $5,081

Assume UV/OX treatment system enclosed by 100 ft by 100 ft fence with two 12 ft gates

376 linear feet of fence at	$10.28 /lf =	$3,865	
2 12 ft gates at	$608 ea. =	$1,216	

3. Testing **$12,240**

Assume 4 technicians and 2 engineers for 3 weeks to test the system

4 Technicians at	$48 /hr for	3 weeks =	$5,760	
2 Engineers at	$54 /hr for	3 weeks =	$6,480	

4. Implementation Costs **$355,971**

Assume Implementation costs at 37% of Capital Costs
Includes Permitting and legal, Services During Construction, Health and Safety,
Report preparation, and engineering design costs.

TOTAL CAPITAL COSTS

Subtotal (ST)	**$1,318,000**
Overhead and Profit @ 15.5%	**$204,000**
Mob/Bond/Insur @ 5% of ST	**$66,000**
Contingency @ 10% of ST	**$132,000**
Total	**$1,720,000**

O&M Costs-

1. Electrical Costs **$5,446**

Transfer System:

Assume	10	HP pump (138 GPM system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation Yrs 1-10 **$238,997**

UVOX Treatment System

ALT. 3 - Treatment System Costs

	Yrs 11-22	**$249,738**
	Yrs 23-23	**$231,817**
	Yrs 24-25	**$0**
	Yrs 26-30	**$0**

A. Labor $212,160

Assume 2 full time employees annually
Assume tasks to include all system sampling/maintenance, Report writing etc.

Assume	1	engineer @	$54	per hour
Assume	1	technician @	$48	per hour

B. Operations Maintenance yrs 1-10 $26,837

Assume system O&M Costs at $0.37 per 1000 gallons water
138 gpm for 8760 hrs per yr = 72,532,800 gallons per year

Operations Maintenance yrs 11-22 $37,578

Assume system O&M Costs at $0.66 per 1000 gallons water
108 gpm for 8760 hrs per yr = 56,764,800 gallons per year

Operations Maintenance yr 23 $19,657

Assume system O&M Costs at $1.10 per 1000 gallons water
34 gpm for 8760 hrs per yr = 17,870,400 gallons per year

Operations Maintenance yrs 0-0 $0

Assume system O&M Costs at $1.10 per 1000 gallons water
0 gpm for 8760 hrs per yr = 0 gallons per year

Operations Maintenance yrs 0-0 $0

Assume system O&M Costs at $1.10 per 1000 gallons water
0 gpm for 8760 hrs per yr = 0 gallons per year

3. Treatment System Influent and Effluent Water Monitoring **$18,624**

Assume 4 samples every month (2 per event, 1 effluent and 1 influent)
Data Validation Labor per Sample = $67
Assume each sampling event includes:
VOCs (EPA 601/SW 8010) $110 /sample
Total (including 15% CLP) = $127 /sample event

TOTAL O&M COSTS Yrs 1-10 **$263,067**

PRESENT WORTH CALCULATIONS

Alt. 3 - UVOX Treatment System (138 GPM capacity)

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$1,720,000	$0	1.0000	$1,720,000	$1,720,000
1	$0	$263,067	0.9302	$263,067	$244,713
2	$0	$263,067	0.8653	$263,067	$227,640
3	$0	$263,067	0.8050	$263,067	$211,759
4	$0	$263,067	0.7488	$263,067	$196,985
5	$0	$263,067	0.6966	$263,067	$183,242
6	$0	$263,067	0.6480	$263,067	$170,457
7	$0	$263,067	0.6028	$263,067	$158,565
8	$0	$263,067	0.5607	$263,067	$147,502
9	$0	$263,067	0.5216	$263,067	$137,211
10	$0	$263,067	0.4852	$263,067	$127,638
11	$0	$273,808	0.4513	$273,808	$123,581
12	$0	$273,808	0.4199	$273,808	$114,959
13	$0	$273,808	0.3906	$273,808	$106,939
14	$0	$273,808	0.3633	$273,808	$99,478
15	$0	$273,808	0.3380	$273,808	$92,538
16	$0	$273,808	0.3144	$273,808	$86,082
17	$0	$273,808	0.2925	$273,808	$80,076
18	$0	$273,808	0.2720	$273,808	$74,489
19	$0	$273,808	0.2531	$273,808	$69,292
20	$0	$273,808	0.2354	$273,808	$64,458
21	$0	$273,808	0.2190	$273,808	$59,961
22	$0	$273,808	0.2037	$273,808	$55,778
23	$0	$255,887	0.1895	$255,887	$48,490
24	$0	$0	0.1763	$0	$0
25	$0	$0	0.1640	$0	$0
26	$0	$0	0.1525	$0	$0
27	$0	$0	0.1419	$0	$0
28	$0	$0	0.1320	$0	$0
29	$0	$0	0.1228	$0	$0
30	$0	$0	0.1142	$0	$0
	$1,720,000	**$6,172,254**			**$4,601,835**

Alt. 3 - UVOX Treatment System (138 GPM capacity) ***$4,600,000***

UVOX Treatment System

ALT 4. - Treatment System Costs

The costs for the system are based on a 586 gallons per minute centralized system. It includes all costs for transfer piping from the individual plumes (see Figure 6.24 of main text), the treatment system, associated foundation, electrical, instrumentation, and piping.
The Operations and Maintenance costs are based on the costs for the transfer piping and Treatment system only.

Costs associated with wells, trenches, extraction piping (from extraction point to transfer pipe header) will be calculated separately.

CAPITAL COSTS

1. Transfer Piping (from extraction piping to treatment system) **$255,213**

HDPE Pipe $255,213

Pipe Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
Ext 4	8,500	425	$4.64	$2.61	$64,731
Ext 6	15,500	775	$4.64	$4.92	$155,594
Rtn 2	14,500	725	$0.92	$1.37	$34,889

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor
(c) Extraction and Return pipes in same trench (only cost for additonal width of trench)

2. Treatment System (586 gpm UV/OX) **$1,058,405**

A. Treatment/Storage/Office Building $163,333

Assume a 60 ft x 60 ft building to house the UV/OX treatment system

Concrete Foundation	133 CY (60ft x 60ft x 1 ft thick)			
Excavation	133 CY at	$3.25	/CY =	$432
Compaction	133 CY at	$2.43	/CY =	$323
Placement	133 CY at	$139.68	/CY =	$18,577
Pre-Engineered Structure	3,600 square ft			

Including Building, Insulation, HVAC unit, Electrical, and Lighting.
Assume $40.00 /square ft = $144,000

B. Power to site $28,446

	Materials	Installation	Subtotal
Oil Filled Pad Mounted 112.5 KVA Transformer	$14,069	$426	$14,495
Watt-hour-meter and current transformers	$1,500	$500	$2,000
600A Main Circuit, breaker distribution	$10,451	$1,500	$11,951

C. UV Oxidation Treatment System $861,545

Cost of System Delivered to site (1 - 120 KW)	$268,000	
Installation (placing and bolting)	$7,385	

UVOX Treatment System

ALT 4. - Treatment System Costs

Cost of PLC (including programming)	$365,000
Installation of PLC	$73,000
Influent and Effluent Holding Tanks	$20,000
Assume the cost of each tank installed =	$10,000
2 tanks at $10,000 each =	$20,000
Transfer Pump (from system to EPS)	$8,160
Cost of Pump and Motor =	$6,800
Installation (assumed at 20% of capital)	$1,360
Flow measuring and control devices	$120,000

Assume $100,000 for all valves, piping, duct work, and flow devices
Labor $20,000 (assumed at 20% of capital)

E. Fencing **$5,081**

Assume UV/OX treatment system enclosed by 100 ft by 100 ft fence with two 12 ft gates

376 linear feet of fence at	$10.28 /lf =	$3,865
2 12 ft gates at	$608 ea. =	$1,216

3. Testing **$12,240**

Assume 4 technicians and 2 engineers for 3 weeks to test the system

4 Technicians at	$48 /hr for	3 weeks =	$5,760
2 Engineers at	$54 /hr for	3 weeks =	$6,480

4. Implementation Costs **$490,568**

Assume Implementation costs at 37% of Capital Costs
Includes Permitting and legal, Services During Construction, Health and Safety, Report preparation, and engineering design costs.

TOTAL CAPITAL COSTS

Subtotal (ST)	**$1,816,000**
Overhead and Profit @ 15.5%	**$281,000**
Mob/Bond/Insur @ 5% of ST	**$91,000**
Contingency @ 10% of ST	**$182,000**
Total	**$2,370,000**

O&M Costs-

1. Electrical Costs **$10,892**

Transfer System:

Assume	20 HP pump (586 GPM system)
Assume	60% Pump Efficiency
Assume	8760 System run time (hours/year)
Assume	$0.050 per kilowatt hour

UVOX Treatment System

ALT 4. - Treatment System Costs

_. Treatment System Operation	Yrs 1-5	**$368,762**
	Yrs 6-21	**$268,704**
	Yrs 22-23	**$231,817**
	Yrs 24-25	**$0**
	Yrs 26-30	**$0**

A. Labor $212,160

Assume 2 full time employees annually
Assume tasks to include all system sampling/maintenance, Report writing etc.

Assume	1	engineer @	$54	per hour
Assume	1	technician @	$48	per hour

B. Operations Maintenance yrs 1-5 $156,602

Assume system O&M Costs at $0.51 per 1000 gallons water
586 gpm for 8760 hrs per yr = 308,001,600 gallons per year

Operations Maintenance yrs 6-21 $56,544

Assume system O&M Costs at $0.33 per 1000 gallons water
326 gpm for 8760 hrs per yr = 171,345,600 gallons per year

Operations Maintenance yrs 22-23 $19,657

Assume system O&M Costs at $1.10 per 1000 gallons water
34 gpm for 8760 hrs per yr = 17,870,400 gallons per year

Operations Maintenance yrs 24-25 $0

Assume system O&M Costs at $1.10 per 1000 gallons water
0 gpm for 8760 hrs per yr = 0 gallons per year

Operations Maintenance yrs 25-30 $0

Assume system O&M Costs at $1.10 per 1000 gallons water
0 gpm for 8760 hrs per yr = 0 gallons per year

3. Treatment System Influent and Effluent Water Monitoring **$18,624**

Assume 4 samples every month (2 per event, 1 effluent and 1 influent)
Data Validation Labor per Sample = $67
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

TOTAL O&M COSTS	Yrs 1-5	**$398,277**
	Yrs 6-21	**$298,220**
	Yrs 22-23	**$261,333**
	Yrs 24-25	**$0**
	Yrs 26-30	**$0**

PRESENT WORTH CALCULATIONS

Alt. 4 - UVOX Treatment System (586 GPM capacity)

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$2,370,000	$0	1.0000	$2,370,000	$2,370,000
1	$0	$398,277	0.9302	$398,277	$370,491
2	$0	$398,277	0.8653	$398,277	$344,642
3	$0	$398,277	0.8050	$398,277	$320,598
4	$0	$398,277	0.7488	$398,277	$298,230
5	$0	$398,277	0.6966	$398,277	$277,423
6	$0	$298,220	0.6480	$298,220	$193,235
7	$0	$298,220	0.6028	$298,220	$179,753
8	$0	$298,220	0.5607	$298,220	$167,212
9	$0	$298,220	0.5216	$298,220	$155,546
10	$0	$298,220	0.4852	$298,220	$144,694
11	$0	$298,220	0.4513	$298,220	$134,599
12	$0	$298,220	0.4199	$298,220	$125,209
13	$0	$298,220	0.3906	$298,220	$116,473
14	$0	$298,220	0.3633	$298,220	$108,347
15	$0	$298,220	0.3380	$298,220	$100,788
16	$0	$298,220	0.3144	$298,220	$93,756
17	$0	$298,220	0.2925	$298,220	$87,215
18	$0	$298,220	0.2720	$298,220	$81,130
19	$0	$298,220	0.2531	$298,220	$75,470
20	$0	$298,220	0.2354	$298,220	$70,205
21	$0	$298,220	0.2190	$298,220	$65,307
22	$0	$261,333	0.2037	$261,333	$53,236
23	$0	$261,333	0.1895	$261,333	$49,522
24	$0	$0	0.1763	$0	$0
25	$0	$0	0.1640	$0	$0
26	$0	$0	0.1525	$0	$0
27	$0	$0	0.1419	$0	$0
28	$0	$0	0.1320	$0	$0
29	$0	$0	0.1228	$0	$0
30	$0	$0	0.1142	$0	$0
	$2,370,000	**$7,285,567**			**$5,983,085**

Alt. 4 - UVOX Treatment System (586 GPM capacity) ***$6,000,000***

UVOX Treatment System

ALT. 5 - Treatment System Costs

The costs for the system are based on a 208 gallons per minute centralized system. It includes all costs for transfer piping from the individual plumes (see Figure 6.25 of main text), the treatment system, associated foundation, electrical, instrumentation, and piping.
The Operations and Maintenance costs are based on the costs for the transfer piping and Treatment system only.

Costs associated with wells, trenches, extraction piping (from extraction point to transfer pipe header) will be calculated separately.

CAPITAL COSTS

1. Transfer Piping (from extraction piping to treatment system) **$134,652**

HDPE Pipe $134,652

Pipe Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
Ext 4	4,500	225	$4.64	$2.61	$34,269
Ext 6	10,000	500	$4.64	$4.92	$100,383

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

2. Treatment System (208 gpm UV/OX) **$833,649**

A. Treatment/Storage/Office Building $72,576

Assume a 40 ft x 40 ft building to house the UV/OX treatment system

Concrete Foundation	59 CY (40ft x 40ft x 1 ft thick)			
Excavation	59 CY at	$3.25	/CY =	$192
Compaction	59 CY at	$2.43	/CY =	$143
Placement	59 CY at	$139.68	/CY =	$8,241

Pre-Engineered Structure 1,600 square ft

Including Building, Insulation, HVAC unit, Electrical, and Lighting.
Assume $40.00 /square ft = $64,000

B. Power to site $28,446

	Materials	Installation	Subtotal
Oil Filled Pad Mounted 112.5 KVA Transformer	$14,069	$426	$14,495
Watt-hour-meter and current transformers	$1,500	$500	$2,000
600A Main Circuit, breaker distribution	$10,451	$1,500	$11,951

C. UV Oxidation Treatment System $727,545

Cost of System Delivered to site (1 - 60 KW)	$134,000
Installation (placing and bolting)	$7,385
Cost of PLC (including programming)	$365,000
Installation of PLC	$73,000

UVOX Treatment System

ALT. 5 - Treatment System Costs

Influent and Effluent Holding Tanks		$20,000
Assume the cost of each tank installed =		$10,000
2 tanks at	$10,000 each =	$20,000
Transfer Pump (from system to EPS)		$8,160
Cost of Pump and Motor =		$6,800
Installation (assumed at 20% of capital)		$1,360
Flow measuring and control devices		$120,000
Assume	$100,000 for all valves, piping, duct work, and flow devices	
Labor	$20,000 (assumed at 20% of capital)	

E. Fencing $5,081

Assume UV/OX treatment system enclosed by 100 ft by 100 ft fence with two 12 ft gates

376 linear feet of fence at	$10.28 /lf =	$3,865
2 12 ft gates at	$608 ea. =	$1,216

3. Testing **$12,240**

Assume 4 technicians and 2 engineers for 3 weeks to test the system

4 Technicians at	$48 /hr for	3 weeks =	$5,760
2 Engineers at	$54 /hr for	3 weeks =	$6,480

4. Implementation Costs **$362,800**

Assume Implementation costs at 37% of Capital Costs
Includes Permitting and legal, Services During Construction, Health and Safety, Report preparation, and engineering design costs.

TOTAL CAPITAL COSTS

Subtotal (ST)	**$1,343,000**
Overhead and Profit @ 15.5%	**$208,000**
Mob/Bond/Insur @ 5% of ST	**$67,000**
Contingency @ 10% of ST	**$134,000**
Total	**$1,752,000**

UVOX Treatment System

ALT. 5 - Treatment System Costs

&M Costs-

1. Electrical Costs **$5,446**

Transfer System:

Assume	10	HP pump (208 GPM system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation

Yrs 1-21	**$265,729**
Yrs 22-23	**$246,955**
Yrs 24-25	**$0**
Yrs 25-30	**$0**
Yrs 25-30	**$0**

A. Labor $212,160

Assume 2 full time employees annually
Assume tasks to include all system sampling/maintenance, Report writing etc.

Assume	1	engineer @	$54	per hour
Assume	1	technician @	$48	per hour

B. Operations Maintenance Yrs 1-21 $53,569

Assume system O&M Costs at $0.49 per 1000 gallons water
208 gpm for 8760 hrs per yr = 109,324,800 gallons per year

Operations Maintenance Yrs 22-23 $34,795

Assume system O&M Costs at $0.66 per 1000 gallons water
100 gpm for 8760 hrs per yr = 52,560,000 gallons per year

Operations Maintenance Yrs 24-25 $0

Assume system O&M Costs at $1.10 per 1000 gallons water
0 gpm for 8760 hrs per yr = 0 gallons per year

Operations Maintenance Yrs 25-30 $0

Assume system O&M Costs at $1.10 per 1000 gallons water
0 gpm for 8760 hrs per yr = 0 gallons per year

Operations Maintenance Yrs 25-30 $0

Assume system O&M Costs at $1.10 per 1000 gallons water
0 gpm for 8760 hrs per yr = 0 gallons per year

3. Treatment System Influent and Effluent Water Monitoring **$18,624**

Assume 4 samples every month (2 per event, 1 effluent and 1 influent)
Data Validation Labor per Sample = $67
Assume each sampling event includes:
VOCs (EPA 601/SW 8010) $110 /sample

ALT. 5 - Treatment System Costs

Total (including 15% CLP) = $127 /sample event

TOTAL O&M COSTS

Yrs 1-21	**$289,799**
Yrs 22-23	**$271,025**
Yrs 24-25	**$0**
Yrs 25-30	**$0**
Yrs 25-30	**$0**

PRESENT WORTH CALCULATIONS

Alt. 5 - UVOX Treatment System (208 GPM capacity)

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$1,752,000	$0	1.0000	$1,752,000	$1,752,000
1	$0	$289,799	0.9302	$289,799	$269,580
2	$0	$289,799	0.8653	$289,799	$250,772
3	$0	$289,799	0.8050	$289,799	$233,277
4	$0	$289,799	0.7488	$289,799	$217,002
5	$0	$289,799	0.6966	$289,799	$201,862
6	$0	$289,799	0.6480	$289,799	$187,779
7	$0	$289,799	0.6028	$289,799	$174,678
8	$0	$289,799	0.5607	$289,799	$162,491
9	$0	$289,799	0.5216	$289,799	$151,154
10	$0	$289,799	0.4852	$289,799	$140,609
11	$0	$289,799	0.4513	$289,799	$130,799
12	$0	$289,799	0.4199	$289,799	$121,673
13	$0	$289,799	0.3906	$289,799	$113,184
14	$0	$289,799	0.3633	$289,799	$105,288
15	$0	$289,799	0.3380	$289,799	$97,942
16	$0	$289,799	0.3144	$289,799	$91,109
17	$0	$289,799	0.2925	$289,799	$84,753
18	$0	$289,799	0.2720	$289,799	$78,840
19	$0	$289,799	0.2531	$289,799	$73,339
20	$0	$289,799	0.2354	$289,799	$68,222
21	$0	$289,799	0.2190	$289,799	$63,463
22	$0	$271,025	0.2037	$271,025	$55,211
23	$0	$271,025	0.1895	$271,025	$51,359
24	$0	$0	0.1763	$0	$0
25	$0	$0	0.1640	$0	$0
26	$0	$0	0.1525	$0	$0
27	$0	$0	0.1419	$0	$0
28	$0	$0	0.1320	$0	$0
29	$0	$0	0.1228	$0	$0
30	$0	$0	0.1142	$0	$0
	$1,752,000	**$6,627,827**			**$4,876,385**

Alt. 5 - UVOX Treatment System (208 GPM capacity) ***$4,900,000***

UVOX Treatment System

ALT. 6 - Treatment System Costs

he costs for the system are based on a 74 gallons per minute centralized system. It includes all costs for transfer piping from the individual plumes (see Figure 6.26 of main text), the treatment system, associated foundation, electrical, instrumentation, and piping.
The Operations and Maintenance costs are based on the costs for the transfer piping and Treatment system only.

Costs associated with wells, trenches, extraction piping (from extraction point to transfer pipe header) will be calculated separately.

CAPITAL COSTS

1. Transfer Piping (from extraction piping to treatment system) **$110,423**

HDPE Pipe $110,423

Pipe Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
Ext 4	14,500	725	$4.64	$2.61	$110,423

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

2. Treatment System (74 gpm UV/OX) **$794,649**

A. Treatment/Storage/Office Building $72,576

Assume a 40 ft x 40 ft building to house the UV/OX treatment system

Concrete Foundation	59 CY (40ft x 40ft x 1 ft thick)			
Excavation	59 CY at	$3.25	/CY =	$192
Compaction	59 CY at	$2.43	/CY =	$143
Placement	59 CY at	$139.68	/CY =	$8,241

Pre-Engineered Structure 1,600 square ft

Including Building, Insulation, HVAC unit, Electrical, and Lighting.
Assume $40.00 /square ft = $64,000

B. Power to site $28,446

	Materials	Installation	Subtotal
Oil Filled Pad Mounted 112.5 KVA Transformer	$14,069	$426	$14,495
Watt-hour-meter and current transformers	$1,500	$500	$2,000
600A Main Circuit, breaker distribution	$10,451	$1,500	$11,951

C. UV Oxidation Treatment System $688,545

Cost of System Delivered to site (1 - 30 KW)	$95,000
Installation (placing and bolting)	$7,385
Cost of PLC (including programming)	$365,000
Installation of PLC	$73,000
Influent and Effluent Holding Tanks	$20,000

ALT. 6 - Treatment System Costs

Assume the cost of each tank installed =			$10,000
2 tanks at	$10,000	each =	$20,000
Transfer Pump (from system to EPS)			$8,160
Cost of Pump and Motor =			$6,800
Installation (assumed at 20% of capital)			$1,360
Flow measuring and control devices			$120,000
Assume	$100,000	for all valves, piping, duct work, and flow devices	
Labor	$20,000	(assumed at 20% of capital)	

E. Fencing **$5,081**

Assume UV/OX treatment system enclosed by 100 ft by 100 ft fence with two 12 ft gates

376 linear feet of fence at	$10.28 /lf =		$3,865
2 12 ft gates at	$608 ea. =		$1,216

3. Testing **$12,240**

Assume 4 technicians and 2 engineers for 3 weeks to test the system

4 Technicians at	$48 /hr for	3 weeks =	$5,760
2 Engineers at	$54 /hr for	3 weeks =	$6,480

4. Implementation Costs **$339,405**

Assume Implementation costs at 37% of Capital Costs
Includes Permitting and legal, Services During Construction, Health and Safety, Report preparation, and engineering design costs.

TOTAL CAPITAL COSTS

Subtotal (ST)	**$1,257,000**
Overhead and Profit @ 15.5%	**$195,000**
Mob/Bond/Insur @ 5% of ST	**$63,000**
Contingency @ 10% of ST	**$126,000**
Total	**$1,641,000**

O&M Costs-

1. Electrical Costs **$5,446**

Transfer System:

Assume	10	HP pump (74 GPM system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation

Yrs 1-22	**$245,006**
Yrs 23-25	**$0**
Yrs 26-30	**$0**

UVOX Treatment System

ALT. 6 - Treatment System Costs

A. Labor $212,160

Assume 2 full time employees annually
Assume tasks to include all system sampling/maintenance, Report writing etc.

Assume	1	engineer @	$54	per hour
Assume	1	technician @	$48	per hour

B. Operations Maintenance Yrs 1-22 $32,846

Assume system O&M Costs at $0.84 per 1000 gallons water
74 gpm for 8760 hrs per yr = 38,894,400 gallons per year

Operations Maintenance Yrs 23-25 $0

Assume system O&M Costs at $1.10 per 1000 gallons water
0 gpm for 8760 hrs per yr = 0 gallons per year

Operations Maintenance Yrs 25-30 $0

Assume system O&M Costs at $1.10 per 1000 gallons water
0 gpm for 8760 hrs per yr = 0 gallons per year

3. Treatment System Influent and Effluent Water Monitoring **$18,624**

Assume 4 samples every month (2 per event, 1 effluent and 1 influent)
Data Validation Labor per Sample = $67
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

TOTAL O&M COSTS	Yrs 1-22	**$269,076**
	Yrs 23-25	**$0**
	Yrs 26-30	**$0**

PRESENT WORTH CALCULATIONS

Alt. 6 - UVOX Treatment System (74 GPM capacity)

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$1,641,000	$0	1.0000	$1,641,000	$1,641,000
1	$0	$269,076	0.9302	$269,076	$250,303
2	$0	$269,076	0.8653	$269,076	$232,840
3	$0	$269,076	0.8050	$269,076	$216,596
4	$0	$269,076	0.7488	$269,076	$201,484
5	$0	$269,076	0.6966	$269,076	$187,427
6	$0	$269,076	0.6480	$269,076	$174,351
7	$0	$269,076	0.6028	$269,076	$162,187
8	$0	$269,076	0.5607	$269,076	$150,872
9	$0	$269,076	0.5216	$269,076	$140,346
10	$0	$269,076	0.4852	$269,076	$130,554
11	$0	$269,076	0.4513	$269,076	$121,446
12	$0	$269,076	0.4199	$269,076	$112,973
13	$0	$269,076	0.3906	$269,076	$105,091
14	$0	$269,076	0.3633	$269,076	$97,759
15	$0	$269,076	0.3380	$269,076	$90,939
16	$0	$269,076	0.3144	$269,076	$84,594
17	$0	$269,076	0.2925	$269,076	$78,692
18	$0	$269,076	0.2720	$269,076	$73,202
19	$0	$269,076	0.2531	$269,076	$68,095
20	$0	$269,076	0.2354	$269,076	$63,344
21	$0	$269,076	0.2190	$269,076	$58,925
22	$0	$269,076	0.2037	$269,076	$54,814
23	$0	$0	0.1895	$0	$0
24	$0	$0	0.1763	$0	$0
25	$0	$0	0.1640	$0	$0
26	$0	$0	0.1525	$0	$0
27	$0	$0	0.1419	$0	$0
28	$0	$0	0.1320	$0	$0
29	$0	$0	0.1228	$0	$0
30	$0	$0	0.1142	$0	$0
	$1,641,000	**$5,919,675**			**$4,497,833**

Alt. 6 - UVOX Treatment System (74 GPM capacity) ***$4,500,000***

UVOX Treatment System

ALT. 7 - Treatment System Costs

The costs for the system are based on a 260 gallons per minute centralized system. It includes all costs for transfer piping from the individual plumes (see Figure 6.27 of main text), the treatment system, associated foundation, electrical, instrumentation, and piping.
The Operations and Maintenance costs are based on the costs for the transfer piping and Treatment system only.

Costs associated with wells, trenches, extraction piping (from extraction point to transfer pipe header) will be calculated separately.

CAPITAL COSTS

1. Transfer Piping (from extraction piping to treatment system) **$178,105**

HDPE Pipe $178,105

Pipe Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
Ext 4	4,500	225	$4.64	$2.61	$34,269
Ext 6	10,000	500	$4.64	$4.92	$100,383
Rtn 2	14,500	725	$0.92	$1.94	$43,453

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor
(c) Extraction and Return pipes in same trench (only cost for additonal width of trench)

2. Treatment System (260 gpm UV/OX) **$794,649**

A. Treatment/Storage/Office Building $72,576

Assume a 40 ft x 40 ft building to house the UV/OX treatment system

Concrete Foundation	59 CY (40ft x 40ft x 1 ft thick)			
Excavation	59 CY at	$3.25	/CY =	$192
Compaction	59 CY at	$2.43	/CY =	$143
Placement	59 CY at	$139.68	/CY =	$8,241
Pre-Engineered Structure	1,600 square ft			
Including Building, Insulation, HVAC unit, Electrical, and Lighting.				
Assume	$40.00 /square ft =	$64,000		

B. Power to site $28,446

	Materials	Installation	Subtotal
Oil Filled Pad Mounted 112.5 KVA Transformer	$14,069	$426	$14,495
Watt-hour-meter and current transformers	$1,500	$500	$2,000
600A Main Circuit, breaker distribution	$10,451	$1,500	$11,951

C. UV Oxidation Treatment System **$688,545**

Cost of System Delivered to site (1 - 30 KW)	$95,000
Installation (placing and bolting)	$7,385
Cost of PLC (including programming)	$365,000

ALT. 7 - Treatment System Costs

Installation of PLC				$73,000
Influent and Effluent Holding Tanks				$20,000
Assume the cost of each tank installed =				$10,000
2 tanks at	$10,000	each =		$20,000
Transfer Pump (from system to EPS)				$8,160
Cost of Pump and Motor =				$6,800
Installation (assumed at 20% of capital)				$1,360
Flow measuring and control devices				$120,000
Assume	$100,000	for all valves, piping, duct work, and flow devices		
Labor	$20,000	(assumed at 20% of capital)		

E. Fencing $5,081

Assume UV/OX treatment system enclosed by 100 ft by 100 ft fence with two 12 ft gates

376 linear feet of fence at	$10.28 /lf =	$3,865	
2 12 ft gates at	$608 ea. =	$1,216	

3. Testing **$12,240**

Assume 4 technicians and 2 engineers for 3 weeks to test the system

4 Technicians at	$48 /hr for	3 weeks =	$5,760	
2 Engineers at	$54 /hr for	3 weeks =	$6,480	

4. Implementation Costs **$364,448**

Assume Implementation costs at 37% of Capital Costs
Includes Permitting and legal, Services During Construction, Health and Safety,
Report preparation, and engineering design costs.

TOTAL CAPITAL COSTS

Subtotal (ST)	**$1,349,000**
Overhead and Profit @ 15.5%	**$209,000**
Mob/Bond/Insur @ 5% of ST	**$67,000**
Contingency @ 10% of ST	**$135,000**
Total	**$1,760,000**

O&M Costs-

1. Electrical Costs **$5,446**

Transfer System:

Assume	10	HP pump (260 GPM system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

ALT. 7 - Treatment System Costs

?. Treatment System Operation	Yrs 1-22	**$265,666**
	Yrs 23-28	**$246,955**
	Yrs 29-30	**$0**
	Yrs 29-30	**$0**
	Yrs 29-30	**$0**

A. Labor $212,160

Assume 2 full time employees annually
Assume tasks to include all system sampling/maintenance, Report writing etc.

Assume	1	engineer @	$54	per hour
Assume	1	technician @	$48	per hour

B. Operations Maintenance Yrs 1-22 $53,506

Assume system O&M Costs at $0.39 per 1000 gallons water
260 gpm for 8760 hrs per yr = 136,656,000 gallons per year

Operations Maintenance Yrs 23-28 $34,795

Assume system O&M Costs at $0.66 per 1000 gallons water
100 gpm for 8760 hrs per yr = 52,560,000 gallons per year

Operations Maintenance Yrs 29-30 $0

Assume system O&M Costs at $1.10 per 1000 gallons water
0 gpm for 8760 hrs per yr = 0 gallons per year

Operations Maintenance Yrs 29-30 $0

Assume system O&M Costs at $0.44 per 1000 gallons water
0 gpm for 0 hrs per yr = 0 gallons per year

Operations Maintenance Yrs 29-30 $0

Assume system O&M Costs at $0.00 per 1000 gallons water
0 gpm for 0 hrs per yr = 0 gallons per year

3. Treatment System Influent and Effluent Water Monitoring **$18,624**

Assume 4 samples every month (2 per event, 1 effluent and 1 influent)
Data Validation Labor per Sample = $67
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

TOTAL O&M COSTS		
	Yrs 1-22	**$289,736**
	Yrs 23-28	**$271,025**
	Yrs 29-30	**$0**
	Yrs 29-30	**$0**
	Yrs 29-30	**$0**

PRESENT WORTH CALCULATIONS

Alt. 7 - UVOX Treatment System (260 GPM capacity)

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$1,760,000	$0	1.0000	$1,760,000	$1,760,000
1	$0	$289,736	0.9302	$289,736	$269,522
2	$0	$289,736	0.8653	$289,736	$250,718
3	$0	$289,736	0.8050	$289,736	$233,226
4	$0	$289,736	0.7488	$289,736	$216,954
5	$0	$289,736	0.6966	$289,736	$201,818
6	$0	$289,736	0.6480	$289,736	$187,738
7	$0	$289,736	0.6028	$289,736	$174,640
8	$0	$289,736	0.5607	$289,736	$162,456
9	$0	$289,736	0.5216	$289,736	$151,121
10	$0	$289,736	0.4852	$289,736	$140,578
11	$0	$289,736	0.4513	$289,736	$130,770
12	$0	$289,736	0.4199	$289,736	$121,647
13	$0	$289,736	0.3906	$289,736	$113,160
14	$0	$289,736	0.3633	$289,736	$105,265
15	$0	$289,736	0.3380	$289,736	$97,921
16	$0	$289,736	0.3144	$289,736	$91,089
17	$0	$289,736	0.2925	$289,736	$84,734
18	$0	$289,736	0.2720	$289,736	$78,822
19	$0	$289,736	0.2531	$289,736	$73,323
20	$0	$289,736	0.2354	$289,736	$68,208
21	$0	$289,736	0.2190	$289,736	$63,449
22	$0	$289,736	0.2037	$289,736	$59,022
23	$0	$271,025	0.1895	$271,025	$51,359
24	$0	$271,025	0.1763	$271,025	$47,776
25	$0	$271,025	0.1640	$271,025	$44,442
26	$0	$271,025	0.1525	$271,025	$41,342
27	$0	$271,025	0.1419	$271,025	$38,457
28	$0	$271,025	0.1320	$271,025	$35,774
29	$0	$0	0.1228	$0	$0
30	$0	$0	0.1142	$0	$0
	$1,760,000	**$8,000,336**			**$5,095,331**

Alt. 7 - UVOX Treatment System (260 GPM capacity) ***$5,100,000***

Plume A - Source Area, Natural Attenuation

;ROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$3,048**

   Assume one sample semiannually until system shutdown
   Assume 1.2 samples/well each sampling event (includes QA samples)
   Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
   Assume 10 existing groundwater monitoring wells for sampling
   Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$3,840**

   Assume rate for 2 sampling technicians @ $48 /hour/technician
   Assume 2 hours/well/sampling event for sampling, shipping, etc.
   Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$1,250**

   Assume rental of sampling equipment, shipping, etc. @ $250/day
   Assume 10 existing groundwater monitoring wells
   Assume 2 hours per well for sampling
   Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

   Assume 1 man-week per sampling event
   Assume chargeout rate for 1 - Validation Chemist @ $67/hour
   Assume 2 sample events/year

TOTAL MONITORING COSTS **$13,498**

PRESENT WORTH CALCULATIONS

Plume A - Source Area, Natural Attenuation

ANNUAL DISCOUNT RATE = 7.5%

YEAR	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$0	1.0000	$0	$0
1	$13,498	0.9302	$13,498	$12,556
2	$13,498	0.8653	$13,498	$11,680
3	$13,498	0.8050	$13,498	$10,865
4	$13,498	0.7488	$13,498	$10,107
5	$13,498	0.6966	$13,498	$9,402
6	$13,498	0.6480	$13,498	$8,746
7	$13,498	0.6028	$13,498	$8,136
8	$13,498	0.5607	$13,498	$7,568
9	$13,498	0.5216	$13,498	$7,040
10	$13,498	0.4852	$13,498	$6,549
11	$13,498	0.4513	$13,498	$6,092
12	$13,498	0.4199	$13,498	$5,667
13	$13,498	0.3906	$13,498	$5,272
14	$13,498	0.3633	$13,498	$4,904
15	$13,498	0.3380	$13,498	$4,562
16	$13,498	0.3144	$13,498	$4,244
17	$13,498	0.2925	$13,498	$3,948
18	$13,498	0.2720	$13,498	$3,672
19	$13,498	0.2531	$13,498	$3,416
20	$13,498	0.2354	$13,498	$3,178
21	$13,498	0.2190	$13,498	$2,956
22	$13,498	0.2037	$13,498	$2,750
23	$13,498	0.1895	$13,498	$2,558
24	$13,498	0.1763	$13,498	$2,379
25	$13,498	0.1640	$13,498	$2,213
26	$13,498	0.1525	$13,498	$2,059
27	$13,498	0.1419	$13,498	$1,915
28	$13,498	0.1320	$13,498	$1,782
29	$13,498	0.1228	$13,498	$1,657
30	$0	0.1142	$0	$0
	$391,442			**$157,875**

Plume A - Source Area, Natural Attenuation ***$200,000***

Plume A - Source Area, In-Situ

APITAL COSTS

1. Bioremediation Extraction Well Installation **$35,432**

A. Drilling **$24,000**

Assume Drilling costs at			$150	per linear foot	
Assume	4	wells at an average depth of		40	ft
Total	4	wells		160	linear feet

B. Pump Installation **$6,204**

Assume Installation technicians @			$48	/hour/technician	
Assume	16	hours per well for pump installation			
4 pumps at	$788	each =	$3,152		
16 hrs/well at	$48	/hr =	$763	per well	
4 wells at	$763	/well =	$3,052	installation	

C. Fencing (assume each well enclosed by 20 ft by 20 ft fence with one 12 ft gate) **$5,228**

68 linear feet of fence per well at	$10.28	/lf =	$699
1 12 ft gates per well at	$608	ea. =	$608
		Subtotal =	$1,307

4 wells at $1,307 /well = $5,228

2. Bioremediation Injection Well Installation **$73,070**

A. Drilling **$60,000**

Assume Drilling costs at			$150	per linear foot	
Assume	10	wells at an average depth of		40	ft
Total	10	wells		400	linear feet

B. Fencing (assume each well enclosed by 20 ft by 20 ft fence with one 12 ft gate) **$13,070**

68 linear feet of fence per well at	$10.28	/lf =	$699
1 12 ft gates per well at	$608	ea. =	$608
		Subtotal =	$1,307

10 wells at $1,307 /well = $13,070

4. Extraction Pipe Installation (from extraction point to header) **$62,338**

A. HDPE Pipe **$41,938**

Pipe I.D., Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
Ext. 2"	2,040	102	$4.64	$1.37	$12,885
Rtn 2"	4,600	230	$4.64	$1.37	$29,054
			Subtotal		$41,938

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

B. Electrical and Instrumentation **$20,400**

Plume A - Source Area, In-Situ

Assume $3,000 per well to install cable, conduit, and handholds
4 wells at $3,000 per well = $12,000
Assume $600 per extraction well to install valves and flow elements
4 wells at $600 per well = $2,400
Assume $600 per injection well to install valves and flow elements
10 wells at $600 per well = $6,000

5. Treatment System (Bioremediation) **$99,069**

A. Treatment/Storage/Office Building $18,180

Assume a 20 ft x 20 ft building to house the each bioremediation treatment system

Concrete Foundation	15 CY (20ft x 20ft x 1 ft thick)		
Excavation	15 CY at	$3.25 /CY =	$49
Compaction	15 CY at	$2.43 /CY =	$36
Placement	15 CY at	$139.68 /CY =	$2,095
Pre-Engineered Structure	400 square ft		

Including Building, Insulation, HVAC unit, Electrical, and Lighting.
Assume $40.00 /square ft = $16,000

B. Power to site $28,446

	Materials	Installation	Subtotal
Oil Filled Pad Mounted 112.5 KVA Transformer	$14,069	$426	$14,495
Watt-hour-meter and current transformers	$1,500	$500	$2,000
600A Main Circuit, breaker distribution	$10,451	$1,500	$11,951

C. In Situ Bioremediation Equipment $46,785

2,000 gallon H20 holding tank		$1,570
27.5 gpm pump		$1,295
1,000 gallon Methanol holding tank		$996
Metering pump		$1,627
Skid, tank penetrations, and delivery		$3,500
Braided Hose		$187
Cost of PLC		$5,942
Installation of PLC		$1,188.40
Programming of PLC		
(assume one engineer and one technician for 6 weeks per system)		
$54 /hr for	6 weeks =	$12,960
$48 /hr for	6 weeks =	$11,520
Flow measuring and control devices		$6,000
Assume $5,000 for all valves and flow devices		
Labor $1,000 (assumed at 20% of capital)		

D. Fencing $5,657

Assume each In-Situ Bioremediation system enclosed by 60 ft by 60 ft fence with two 12 ft gate

432 linear feet of fence at	$10.28 /lf =	$4,441
2 12 ft gates at	$608 ea. =	$1,216

6. Treatment System (40 gpm UV/OX) **$166,300**

Based on a ratio of flow rates relative to the cost of a 400 GPM system $166,300
System flow = 40 gpm

Plume A - Source Area, In-Situ

Cost of	400 gpm system =	$1,663,000
Cost of the	40 gpm system =	$166,300

7. Testing **$12,240**

Assume 4 technicians and 2 engineers for 3 weeks to test the system

4 Technicians at	$48 /hr for	3 weeks =	$5,760
2 Engineers at	$54 /hr for	3 weeks =	$6,480

8. Implementation Costs **$104,395**

Without Treatment System **$99,867**

Assume Implementation costs at 37% of Capital Costs
Includes Permitting and legal, Services During Construction, Health and Safety,
Report preparation, and engineering design costs.

TOTAL CAPITAL COSTS

Without Treatment System		With Treatment System	
Subtotal (ST)	**$382,000**	Subtotal (ST)	**$553,000**
Overhead and Profit @ 15.5%	**$59,000**	Overhead and Profit @ 15.5%	**$86,000**
Mob/Bond/Insur @ 5% of ST	**$19,000**	Mob/Bond/Insur @ 5% of ST	**$28,000**
Contingency @ 10% of ST	**$38,000**	Contingency @ 10% of ST	**$55,000**
Total	**$498,000**	Total	**$722,000**

O&M COSTS

.. Electrical Costs **$2,178**

Extraction System:

Assume	4	HP pump (Bioremediation system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation **$85,914**

A. Labor and Maintenance **$31,011**

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	40 gpm	
Cost of	400 gpm system =	$310,111
Cost of the	40 gpm system =	$31,011

B. Treatment System Influent and Effluent Water Monitoring **$1,862**

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	40 gpm	
Cost of	400 gpm system =	$18,624
Cost of the	40 gpm system =	$1,862

C. Insitu Bio System Operation **$53,040**

Assume 1 technician and 1 engineer quarter time to operate the system

1 Technician at	$48 /hr for	13 weeks =	$24,960
1 Engineer at	$54 /hr for	13 weeks =	$28,080

3. Extraction Well Pump Replacement **$6,204**

Assume extraction pumps will require replacement every 5 years

Assume Installation technicians @			$48	/hour/technician
Assume	16	hours per well for pump installation		
4 pumps at	$788	each =	$3,152	
16 hrs/well at	$48	/hr =	$763	per well
4 wells at	$763	/well =	$3,052	installation

TOTAL O&M COSTS

Total O&M with Treatment System Costs	**$88,092**
O&M with 5 year Replacement	**$94,296**
Total O&M without Treatment System Costs	**$55,218**
O&M with 5 year Replacement	**$61,422**

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$3,048**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 10 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$3,840**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$1,250**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 10 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$13,498**

PRESENT WORTH CALCULATIONS

Plume A - Source Area, In-Situ Treatment - with 400 GPM Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$722,000	$0	$0	1.0000	$722,000	$722,000
1	$0	$88,092	$13,498	0.9302	$101,590	$94,502
2	$0	$88,092	$13,498	0.8653	$101,590	$87,909
3	$0	$88,092	$13,498	0.8050	$101,590	$81,776
4	$0	$88,092	$13,498	0.7488	$101,590	$76,071
5	$0	$94,296	$13,498	0.6966	$107,794	$75,085
6	$0	$88,092	$13,498	0.6480	$101,590	$65,826
7	$0	$88,092	$13,498	0.6028	$101,590	$61,234
8	$0	$88,092	$13,498	0.5607	$101,590	$56,962
9	$0	$88,092	$13,498	0.5216	$101,590	$52,988
10	$0	$88,092	$13,498	0.4852	$101,590	$49,291
11	$0	$0	$13,498	0.4513	$13,498	$6,092
12	$0	$0	$13,498	0.4199	$13,498	$5,667
13	$0	$0	$13,498	0.3906	$13,498	$5,272
14	$0	$0	$13,498	0.3633	$13,498	$4,904
15	$0	$0	$13,498	0.3380	$13,498	$4,562
16	$0	$0	$13,498	0.3144	$13,498	$4,244
17	$0	$0	$13,498	0.2925	$13,498	$3,948
18	$0	$0	$13,498	0.2720	$13,498	$3,672
19	$0	$0	$13,498	0.2531	$13,498	$3,416
20	$0	$0	$13,498	0.2354	$13,498	$3,178
21	$0	$0	$13,498	0.2190	$13,498	$2,956
22	$0	$0	$13,498	0.2037	$13,498	$2,750
23	$0	$0	$13,498	0.1895	$13,498	$2,558
24	$0	$0	$13,498	0.1763	$13,498	$2,379
25	$0	$0	$13,498	0.1640	$13,498	$2,213
26	$0	$0	$13,498	0.1525	$13,498	$2,059
27	$0	$0	$0	0.1419	$0	$0
28	$0	$0	$0	0.1320	$0	$0
29	$0	$0	$0	0.1228	$0	$0
30	$0	$0	$0	0.1142	$0	$0
	$722,000	$887,123	$350,948			$1,483,512

Plume A - Source Area, In-Situ Treatment ***$1,500,000***

PRESENT WORTH CALCULATIONS

Plume A - Source Area, In-Situ Treatment - without 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$498,000	$0	$0	1.0000	$498,000	$498,000
1	$0	$55,218	$13,498	0.9302	$68,716	$63,922
2	$0	$55,218	$13,498	0.8653	$68,716	$59,462
3	$0	$55,218	$13,498	0.8050	$68,716	$55,314
4	$0	$55,218	$13,498	0.7488	$68,716	$51,455
5	$0	$61,422	$13,498	0.6966	$74,920	$52,186
6	$0	$55,218	$13,498	0.6480	$68,716	$44,526
7	$0	$55,218	$13,498	0.6028	$68,716	$41,419
8	$0	$55,218	$13,498	0.5607	$68,716	$38,529
9	$0	$55,218	$13,498	0.5216	$68,716	$35,841
10	$0	$55,218	$13,498	0.4852	$68,716	$33,341
11	$0	$0	$13,498	0.4513	$13,498	$6,092
12	$0	$0	$13,498	0.4199	$13,498	$5,667
13	$0	$0	$13,498	0.3906	$13,498	$5,272
14	$0	$0	$13,498	0.3633	$13,498	$4,904
15	$0	$0	$13,498	0.3380	$13,498	$4,562
16	$0	$0	$13,498	0.3144	$13,498	$4,244
17	$0	$0	$13,498	0.2925	$13,498	$3,948
18	$0	$0	$13,498	0.2720	$13,498	$3,672
19	$0	$0	$13,498	0.2531	$13,498	$3,416
20	$0	$0	$13,498	0.2354	$13,498	$3,178
21	$0	$0	$13,498	0.2190	$13,498	$2,956
22	$0	$0	$13,498	0.2037	$13,498	$2,750
23	$0	$0	$13,498	0.1895	$13,498	$2,558
24	$0	$0	$13,498	0.1763	$13,498	$2,379
25	$0	$0	$13,498	0.1640	$13,498	$2,213
26	$0	$0	$13,498	0.1525	$13,498	$2,059
27	$0	$0	$0	0.1419	$0	$0
28	$0	$0	$0	0.1320	$0	$0
29	$0	$0	$0	0.1228	$0	$0
30	$0	$0	$0	0.1142	$0	$0
	$498,000	**$558,387**	**$350,948**			**$1,033,865**

Plume A - Source Area, In-Situ Treatment ***$1,000,000***

Plume A - Source Area, Exsitu

CAPITAL COSTS

1. Collector Trench Installation **$233,160**

Assume Trench costs at $225 /linear foot
Assume 1,000 linear feet of trench
1,000 lf at $225 /lf = $225,000
Includes trench and sumps installed at 300 ft intervals

Pump Installation
Assume 4 pump stations
Cost of Pump and Motor = $1,700
Installation (assumed at 20% of capital) $340
Subtotal $2,040

4 pumps at $2,040 each = $8,160

2. Extraction Pipe Installation (from extraction point to header) **$33,980**

A. HDPE Pipe $19,580

Pipe I.D., Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
2	3,100	155	$4.64	$1.37	$19,580
				Subtotal	$19,580

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

B. Electrical and Instrumentation $14,400

Assume $3,000 per pump station to install cable, conduit, and handholds
4 stations at $3,000 per station $12,000

Assume $600 per pump station to install valves and flow elements
4 stations at $600 per station $2,400

3. Treatment System (34 gpm UV/OX) **$184,450**

A. Treatment System $184,450

Based on a ratio of flow rates relative to the cost of a 400 GPM system
System flow = 34 gpm
Cost of 400 gpm system = $2,170,000
Cost of the 34 gpm system = $184,450

TOTAL CAPITAL COSTS

Without Treatment System		With Treatment System	
Subtotal (ST)	**$267,140**	Subtotal (ST)	**$452,000**
Overhead and Profit @ 15.5%	**$41,000**	Overhead and Profit @ 15.5%	**$70,000**
Mob/Bond/Insur @ 5% of ST	**$13,000**	Mob/Bond/Insur @ 5% of ST	**$23,000**
Contingency @ 10% of ST	**$27,000**	Contingency @ 10% of ST	**$45,000**
Total	**$348,140**	Total	**$590,000**

Plume A - Source Area, Exsitu

O&M Costs-

1. Electrical Costs **$4,901**

Extraction System:

Assume	9	HP pump (35 GPM system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation **$27,943**

A. Labor and Maintenance $26,359

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	34	gpm	
Cost of	400	gpm system =	$310,111
Cost of the	34	gpm system =	$26,359

B. Treatment System Influent and Effluent Water Monitoring $1,583

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	34	gpm	
Cost of	400	gpm system =	$18,624
Cost of the	34	gpm system =	$1,583

3. Extraction Trench Pump Replacement **$3,915**

Assume extraction pumps will require replacement every 5 years

Assume Installation technicians @ $48 /hour/technician

Assume 16 hours per well for pump installation

4 pumps at	$788	each =	$3,152	
16 hrs/pump at	$48	/hr =	$763	per pump

Total O&M Costs With Treatment System	**$32,844**
O&M with 5 year Replacement	**$36,759**
Total O&M Costs Without Treatment System	**$4,901**
O&M with 5 year Replacement	**$8,816**

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$3,048**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 10 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$3,840**

Plume A - Source Area, Exsitu

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$1,250**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 10 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$13,498**

PRESENT WORTH CALCULATIONS

Plume A - Source Area, Exsitu - with 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$590,000	$0	$0	1.0000	$590,000	$590,000
1	$0	$32,844	$13,498	0.9302	$46,342	$43,109
2	$0	$32,844	$13,498	0.8653	$46,342	$40,101
3	$0	$32,844	$13,498	0.8050	$46,342	$37,303
4	$0	$32,844	$13,498	0.7488	$46,342	$34,701
5	$0	$36,759	$13,498	0.6966	$50,257	$35,007
6	$0	$32,844	$13,498	0.6480	$46,342	$30,028
7	$0	$32,844	$13,498	0.6028	$46,342	$27,933
8	$0	$32,844	$13,498	0.5607	$46,342	$25,984
9	$0	$32,844	$13,498	0.5216	$46,342	$24,171
10	$0	$36,759	$13,498	0.4852	$50,257	$24,384
11	$0	$32,844	$13,498	0.4513	$46,342	$20,916
12	$0	$32,844	$13,498	0.4199	$46,342	$19,457
13	$0	$32,844	$13,498	0.3906	$46,342	$18,099
14	$0	$32,844	$13,498	0.3633	$46,342	$16,837
15	$0	$36,759	$13,498	0.3380	$50,257	$16,985
16	$0	$32,844	$13,498	0.3144	$46,342	$14,569
17	$0	$32,844	$13,498	0.2925	$46,342	$13,553
18	$0	$32,844	$13,498	0.2720	$46,342	$12,607
19	$0	$32,844	$13,498	0.2531	$46,342	$11,728
20	$0	$36,759	$13,498	0.2354	$50,257	$11,831
21	$0	$32,844	$13,498	0.2190	$46,342	$10,148
22	$0	$32,844	$13,498	0.2037	$46,342	$9,440
23	$0	$0	$13,498	0.1895	$13,498	$2,558
24	$0	$0	$13,498	0.1763	$13,498	$2,379
25	$0	$0	$13,498	0.1640	$13,498	$2,213
26	$0	$0	$13,498	0.1525	$13,498	$2,059
27	$0	$0	$0	0.1419	$0	$0
28	$0	$0	$0	0.1320	$0	$0
29	$0	$0	$0	0.1228	$0	$0
30	$0	$0	$0	0.1142	$0	$0
	$590,000	**$738,222**	**$350,948**			**$1,098,100**

Plume A - Source Area, Exsitu ***$1,100,000***

PRESENT WORTH CALCULATIONS

Plume A - Source Area, Exsitu - without 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$348,140	$0	$0	1.0000	$348,140	$348,140
1	$0	$4,901	$13,498	0.9302	$18,399	$17,116
2	$0	$4,901	$13,498	0.8653	$18,399	$15,921
3	$0	$4,901	$13,498	0.8050	$18,399	$14,811
4	$0	$4,901	$13,498	0.7488	$18,399	$13,777
5	$0	$8,816	$13,498	0.6966	$22,314	$15,543
6	$0	$4,901	$13,498	0.6480	$18,399	$11,922
7	$0	$4,901	$13,498	0.6028	$18,399	$11,090
8	$0	$4,901	$13,498	0.5607	$18,399	$10,316
9	$0	$4,901	$13,498	0.5216	$18,399	$9,597
10	$0	$8,816	$13,498	0.4852	$22,314	$10,827
11	$0	$4,901	$13,498	0.4513	$18,399	$8,304
12	$0	$4,901	$13,498	0.4199	$18,399	$7,725
13	$0	$4,901	$13,498	0.3906	$18,399	$7,186
14	$0	$4,901	$13,498	0.3633	$18,399	$6,685
15	$0	$8,816	$13,498	0.3380	$22,314	$7,541
16	$0	$4,901	$13,498	0.3144	$18,399	$5,784
17	$0	$3,100	$13,498	0.2925	$16,598	$4,854
18	$0	$4,901	$13,498	0.2720	$18,399	$5,005
19	$0	$4,901	$13,498	0.2531	$18,399	$4,656
20	$0	$8,816	$13,498	0.2354	$22,314	$5,253
21	$0	$4,901	$13,498	0.2190	$18,399	$4,029
22	$0	$4,901	$13,498	0.2037	$18,399	$3,748
23	$0	$0	$13,498	0.1895	$13,498	$2,558
24	$0	$0	$13,498	0.1763	$13,498	$2,379
25	$0	$0	$13,498	0.1640	$13,498	$2,213
26	$0	$0	$13,498	0.1525	$13,498	$2,059
27	$0	$0	$13,498	0.1419	$13,498	$1,915
28	$0	$0	$13,498	0.1320	$13,498	$1,782
29	$0	$0	$13,498	0.1228	$13,498	$1,657
30	$0	$0	$0	0.1142	$0	$0
	$348,140	**$121,686**	**$391,442**			**$564,396**

Plume A - Source Area, Exsitu ***$600,000***

Plume A - Perimeter, Natural Attenuation

ROUNDWATER MONITORING	**$13,498**
1. Groundwater Monitoring and Extraction Well Sample Analysis	**$3,048**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 10 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling)	**$3,840**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling)	**$1,250**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 10 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data)	**$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS	**$13,498**

PRESENT WORTH CALCULATIONS

Plume A - Perimeter, Natural Attenuation

ANNUAL DISCOUNT RATE = 7.5%

YEAR	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$0	1.0000	$0	$0
1	$13,498	0.9302	$13,498	$12,556
2	$13,498	0.8653	$13,498	$11,680
3	$13,498	0.8050	$13,498	$10,865
4	$13,498	0.7488	$13,498	$10,107
5	$13,498	0.6966	$13,498	$9,402
6	$13,498	0.6480	$13,498	$8,746
7	$13,498	0.6028	$13,498	$8,136
8	$13,498	0.5607	$13,498	$7,568
9	$13,498	0.5216	$13,498	$7,040
10	$13,498	0.4852	$13,498	$6,549
11	$13,498	0.4513	$13,498	$6,092
12	$13,498	0.4199	$13,498	$5,667
13	$13,498	0.3906	$13,498	$5,272
14	$13,498	0.3633	$13,498	$4,904
15	$13,498	0.3380	$13,498	$4,562
16	$13,498	0.3144	$13,498	$4,244
17	$13,498	0.2925	$13,498	$3,948
18	$13,498	0.2720	$13,498	$3,672
19	$13,498	0.2531	$13,498	$3,416
20	$13,498	0.2354	$13,498	$3,178
21	$13,498	0.2190	$13,498	$2,956
22	$13,498	0.2037	$13,498	$2,750
23	$13,498	0.1895	$13,498	$2,558
24	$13,498	0.1763	$13,498	$2,379
25	$13,498	0.1640	$13,498	$2,213
26	$13,498	0.1525	$13,498	$2,059
27	$13,498	0.1419	$13,498	$1,915
28	$13,498	0.1320	$13,498	$1,782
29	$13,498	0.1228	$13,498	$1,657
30	$0	0.1142	$0	$0
	$391,442			**$157,875**

Plume A - Perimeter, Natural Attenuation ***$200,000***

Plume A - Perimeter, Ex-Situ

CAPITAL COSTS

1. Extraction Well Installation **$124,013**

A. Drilling $84,000

Assume Drilling costs at $150 per linear foot
Assume 14 wells at an average depth of 40 ft
Total 14 wells 560 linear feet

B. Pump Installation $21,714

Assume Installation technicians @ $48 /hour/technician
Assume 16 hours per well for pump installation

14 pumps at	$788	each =	$11,032	
16 hrs/well at	$48	/hr =	$763	per well
14 wells at	$763	/well =	$10,682	installation

C. Fencing (assume each well enclosed by 20 ft by 20 ft fence with one 12 ft gate) $18,299

68 linear feet of fence per well at	$10.28	/lf =	$699
1 12 ft gates per well at	$608	ea. =	$608
		Subtotal =	$1,307

14 wells at $1,307 /well = $18,299

4. Extraction Pipe Installation (from extraction point to header) **$113,795**

A. HDPE Pipe $63,395

Pipe I.D., Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Unit Cost Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
2	2,200	110	$4.64	$1.37	$13,895
4	6,500	325	$4.64	$2.61	$49,500
				Subtotal	$63,395

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

B. Electrical and Instrumentation $50,400

Assume $3,000 per well to install cable, conduit, and handholds
14 wells at $3,000 per well = $42,000
Assume $600 per well to install valves and flow elements
14 wells at $600 per well = $8,400

6. Treatment System (100 gpm UV/OX) **$542,500**

A. Treatment System $542,500

Based on a ratio of flow rates relative to the cost of a 400 GPM system
System flow = 100 gpm
Cost of 400 gpm system = $2,170,000
Cost of the 100 gpm system = $542,500

Plume A - Perimeter, Ex-Situ

CAPITAL COSTS

Without Treatment System		With Treatment System	
Subtotal (ST)	**$237,808**	Subtotal (ST)	**$780,000**
Overhead and Profit @ 15.5%	**$37,000**	Overhead and Profit @ 15.5%	**$121,000**
Mob/Bond/Insur @ 5% of ST	**$12,000**	Mob/Bond/Insur @ 5% of ST	**$39,000**
Contingency @ 10% of ST	**$24,000**	Contingency @ 10% of ST	**$78,000**
Total	**$310,808**	Total	**$1,018,000**

O&M COSTS

1. Electrical Costs **$5,718**

Extraction System:

Assume	10.5	HP pump (100 GPM system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operations and Maintenance **$82,184**

A. Labor and Maintenance $77,528

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	100 gpm	
Cost of	400 gpm system =	$310,111
Cost of the	100 gpm system =	$77,528

B. Treatment System Influent and Effluent Water Monitoring $4,656

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	100 gpm	
Cost of	400 gpm system =	$18,624
Cost of the	100 gpm system =	$4,656

3. Extraction Well Pump Replacement **$21,714**

Assume extraction pumps will require replacement every 5 years

Assume Installation technicians @			$48	/hour/technician
Assume	16	hours per well for pump installation		
14 pumps at	$788	each =	$11,032	
16 hrs/well at	$48	/hr =	$763	per well
14 wells at	$763	/well =	$10,682	installation

Without Treatment System	**$87,902**
O&M with 5 year Replacement	**$109,616**
Without Treatment System	**$5,718**
O&M with 5 year Replacement	**$27,432**

GROUNDWATER MONITORING

Plume A - Perimeter, Ex-Situ

Groundwater Monitoring and Extraction Well Sample Analysis	**$3,048**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 10 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling)	**$3,840**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling)	**$1,250**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 10 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data)	**$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS	**$13,498**

PRESENT WORTH CALCULATIONS

Plume A - Perimeter, Ex-Situ - with 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$1,018,000	$0	$0	1.0000	$1,018,000	$1,018,000
1	$0	$87,902	$13,498	0.9302	$101,400	$94,326
2	$0	$87,902	$13,498	0.8653	$101,400	$87,745
3	$0	$87,902	$13,498	0.8050	$101,400	$81,623
4	$0	$87,902	$13,498	0.7488	$101,400	$75,928
5	$0	$109,616	$13,498	0.6966	$123,114	$85,756
6	$0	$87,902	$13,498	0.6480	$101,400	$65,703
7	$0	$87,902	$13,498	0.6028	$101,400	$61,119
8	$0	$87,902	$13,498	0.5607	$101,400	$56,855
9	$0	$87,902	$13,498	0.5216	$101,400	$52,889
10	$0	$109,616	$13,498	0.4852	$123,114	$59,734
11	$0	$87,902	$13,498	0.4513	$101,400	$45,766
12	$0	$87,902	$13,498	0.4199	$101,400	$42,573
13	$0	$87,902	$13,498	0.3906	$101,400	$39,603
14	$0	$87,902	$13,498	0.3633	$101,400	$36,840
15	$0	$109,616	$13,498	0.3380	$123,114	$41,608
16	$0	$87,902	$13,498	0.3144	$101,400	$31,879
17	$0	$87,902	$13,498	0.2925	$101,400	$29,655
18	$0	$87,902	$13,498	0.2720	$101,400	$27,586
19	$0	$87,902	$13,498	0.2531	$101,400	$25,661
20	$0	$109,616	$13,498	0.2354	$123,114	$28,983
21	$0	$87,902	$13,498	0.2190	$101,400	$22,205
22	$0	$87,902	$13,498	0.2037	$101,400	$20,656
23	$0	$87,902	$13,498	0.1895	$101,400	$19,215
24	$0	$87,902	$13,498	0.1763	$101,400	$17,875
25	$0	$109,616	$13,498	0.1640	$123,114	$20,188
26	$0	$87,902	$13,498	0.1525	$101,400	$15,467
27	$0	$87,902	$13,498	0.1419	$101,400	$14,388
28	$0	$0	$0	0.1320	$0	$0
29	$0	$0	$0	0.1228	$0	$0
30	$0	$0	$0	0.1142	$0	$0
	$1,018,000	**$2,481,922**	**$364,446**			**$2,219,827**

Plume A - Perimeter, Ex-Situ ***$2,200,000***

PRESENT WORTH CALCULATIONS

Plume A - Perimeter, Ex-Situ - without 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$310,808	$0	$0	1.0000	$310,808	$310,808
1	$0	$5,718	$13,498	0.9302	$19,216	$17,875
2	$0	$5,718	$13,498	0.8653	$19,216	$16,628
3	$0	$5,718	$13,498	0.8050	$19,216	$15,468
4	$0	$5,718	$13,498	0.7488	$19,216	$14,389
5	$0	$27,432	$13,498	0.6966	$40,930	$28,510
6	$0	$5,718	$13,498	0.6480	$19,216	$12,451
7	$0	$5,718	$13,498	0.6028	$19,216	$11,583
8	$0	$5,718	$13,498	0.5607	$19,216	$10,775
9	$0	$5,718	$13,498	0.5216	$19,216	$10,023
10	$0	$27,432	$13,498	0.4852	$40,930	$19,859
11	$0	$5,718	$13,498	0.4513	$19,216	$8,673
12	$0	$5,718	$13,498	0.4199	$19,216	$8,068
13	$0	$5,718	$13,498	0.3906	$19,216	$7,505
14	$0	$5,718	$13,498	0.3633	$19,216	$6,981
15	$0	$27,432	$13,498	0.3380	$40,930	$13,833
16	$0	$5,718	$13,498	0.3144	$19,216	$6,041
17	$0	$5,718	$13,498	0.2925	$19,216	$5,620
18	$0	$5,718	$13,498	0.2720	$19,216	$5,228
19	$0	$5,718	$13,498	0.2531	$19,216	$4,863
20	$0	$27,432	$13,498	0.2354	$40,930	$9,635
21	$0	$5,718	$13,498	0.2190	$19,216	$4,208
22	$0	$0	$13,498	0.2037	$13,498	$2,750
23	$0	$0	$13,498	0.1895	$13,498	$2,558
24	$0	$0	$13,498	0.1763	$13,498	$2,379
25	$0	$0	$13,498	0.1640	$13,498	$2,213
26	$0	$0	$13,498	0.1525	$13,498	$2,059
27	$0	$0	$0	0.1419	$0	$0
28	$0	$0	$0	0.1320	$0	$0
29	$0	$0	$0	0.1228	$0	$0
30	$0	$0	$0	0.1142	$0	$0
	$310,808	$206,936	$350,948			$560,984

Plume A - Perimeter, Ex-Situ ***$600,000***

Plume A - Off Base, Natural Attenuation

ROUNDWATER MONITORING

1. Groundwater Monitoring and Extraction Well Sample Analysis **$3,048**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 10 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$3,840**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$1,250**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 10 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$13,498**

PRESENT WORTH CALCULATIONS

Plume A - Off Base, Natural Attenuation

ANNUAL DISCOUNT RATE = 7.5%

YEAR	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$0	1.0000	$0	$0
1	$13,498	0.9302	$13,498	$12,556
2	$13,498	0.8653	$13,498	$11,680
3	$13,498	0.8050	$13,498	$10,865
4	$13,498	0.7488	$13,498	$10,107
5	$13,498	0.6966	$13,498	$9,402
6	$13,498	0.6480	$13,498	$8,746
7	$13,498	0.6028	$13,498	$8,136
8	$13,498	0.5607	$13,498	$7,568
9	$13,498	0.5216	$13,498	$7,040
10	$13,498	0.4852	$13,498	$6,549
11	$13,498	0.4513	$13,498	$6,092
12	$13,498	0.4199	$13,498	$5,667
13	$13,498	0.3906	$13,498	$5,272
14	$13,498	0.3633	$13,498	$4,904
15	$13,498	0.3380	$13,498	$4,562
16	$13,498	0.3144	$13,498	$4,244
17	$13,498	0.2925	$13,498	$3,948
18	$13,498	0.2720	$13,498	$3,672
19	$13,498	0.2531	$13,498	$3,416
20	$13,498	0.2354	$13,498	$3,178
21	$13,498	0.2190	$13,498	$2,956
22	$13,498	0.2037	$13,498	$2,750
23	$13,498	0.1895	$13,498	$2,558
24	$13,498	0.1763	$13,498	$2,379
25	$13,498	0.1640	$13,498	$2,213
26	$13,498	0.1525	$13,498	$2,059
27	$0	0.1419	$0	$0
28	$0	0.1320	$0	$0
29	$0	0.1228	$0	$0
30	$0	0.1142	$0	$0
	$350,948			**$152,520**

Plume A - Off Base, Natural Attenuation ***$200,000***

Plume A - Off Base, Exsitu

APITAL COSTS

1. Extraction Well Installation **$212,593**

A. Drilling $144,000

Assume Drilling costs at			$150	per linear foot	
Assume	24	wells at an average depth of		40	ft
Total	24	wells		960	linear feet

B. Pump Installation $37,224

Assume Installation technicians @			$48	/hour/technician
Assume	16	hours per well for pump installation		
24 pumps at	$788	each =	$18,912	
16 hrs/well at	$48	/hr =	$763	per well
24 wells at	$763	/well =	$18,312	installation

C. Fencing (assume each well enclosed by 20 ft by 20 ft fence with one 12 ft gate) $31,369

68 linear feet of fence per well at	$10.28	/lf =	$699
1 12 ft gates per well at	$608	ea. =	$608
		Subtotal =	$1,307
24 wells at $1,307 /well =	$31,369		

2. Extraction Pipe Installation (from extraction point to header) **$131,396**

A. HDPE Pipe $44,996

Pipe I.D., Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Unit Cost Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
1	440	22	$4.64	$1.04	$2,623
2	2,320	116	$4.64	$1.37	$14,653
4	3,640	182	$4.64	$2.61	$27,720
			Subtotal		$44,996

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

B. Electrical and Instrumentation $86,400

Assume	$3,000	per well to install cable, conduit, and handholds		
24 wells at	$3,000	per well =	$72,000	
Assume	$600	per well to install valves and flow elements		
24 wells at	$600	per well =	$14,400	

3. Treatment System (100 gpm UV/OX) **$542,500**

A. Treatment System $542,500

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	100 gpm	
Cost of	400 gpm system =	$2,170,000
Cost of the	100 gpm system =	$542,500

Plume A - Off Base, Exsitu

Without Treatment System		With Treatment System	
Subtotal (ST)	**$343,989**	Subtotal (ST)	**$886,000**
Overhead and Profit @ 15.5%	**$53,000**	Overhead and Profit @ 15.5%	**$137,000**
Mob/Bond/Insur @ 5% of ST	**$17,000**	Mob/Bond/Insur @ 5% of ST	**$44,000**
Contingency @ 10% of ST	**$34,000**	Contingency @ 10% of ST	**$89,000**
Total	**$447,989**	Total	**$1,156,000**

O&M COSTS

1. Electrical Costs **$9,802**

Extraction System:

Assume	18	HP pump (100 GPM system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation **$77,528**

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	100 gpm	
Cost of	400 gpm system =	$310,111
Cost of the	100 gpm system =	$77,528

3. Extraction Well Pump Replacement **$37,224**

Assume extraction pumps will require replacement every 5 years

Assume Installation technicians @ $48 /hour/technician

Assume 16 hours per well for pump installation

24 pumps at	$788	each =	$18,912	
16 hrs/well at	$48	/hr =	$763	per well
24 wells at	$763	/well =	$18,312	installation

Total O&M with Treatment System Costs	**$87,330**
O&M with 5 year Replacement	**$124,554**
Total O&M without Treatment System Costs	**$9,802**
O&M with 5 year Replacement	**$47,026**

GROUNDWATER MONITORING

1. Groundwater Monitoring and Extraction Well Sample Analysis **$3,048**

Assume one sample semiannually until system shutdown

Assume 1.2 samples/well each sampling event (includes QA samples)

Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples

Assume 10 existing groundwater monitoring wells for sampling

Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110 /sample
Total (including 15% CLP) =	$127 /sample event

2. Labor (for Groundwater Well Sampling) **$3,840**

Assume rate for 2 sampling technicians @ $48 /hour/technician

Plume A - Off Base, Exsitu

Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling)	**$1,250**
Assume rental of sampling equipment, shipping, etc. @ $250/day	
Assume 10 existing groundwater monitoring wells	
Assume 2 hours per well for sampling	
Assume 2 sample events/year	
4. Labor (for Data Analysis and Validation of Groundwater Data)	**$5,360**
Assume 1 man-week per sampling event	
Assume chargeout rate for 1 - Validation Chemist @ $67/hour	
Assume 2 sample events/year	
TOTAL MONITORING COSTS	**$13,498**

PRESENT WORTH CALCULATIONS

Plume A - Off Base, Exsitu - with 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$1,156,000	$0	$0	1.0000	$1,156,000	$1,156,000
1	$0	$87,330	$13,498	0.9302	$100,828	$93,794
2	$0	$87,330	$13,498	0.8653	$100,828	$87,250
3	$0	$87,330	$13,498	0.8050	$100,828	$81,163
4	$0	$87,330	$13,498	0.7488	$100,828	$75,500
5	$0	$124,554	$13,498	0.6966	$138,052	$96,162
6	$0	$87,330	$13,498	0.6480	$100,828	$65,333
7	$0	$87,330	$13,498	0.6028	$100,828	$60,775
8	$0	$87,330	$13,498	0.5607	$100,828	$56,535
9	$0	$87,330	$13,498	0.5216	$100,828	$52,590
10	$0	$124,554	$13,498	0.4852	$138,052	$66,982
11	$0	$87,330	$13,498	0.4513	$100,828	$45,508
12	$0	$87,330	$13,498	0.4199	$100,828	$42,333
13	$0	$87,330	$13,498	0.3906	$100,828	$39,380
14	$0	$87,330	$13,498	0.3633	$100,828	$36,632
15	$0	$124,554	$13,498	0.3380	$138,052	$46,657
16	$0	$87,330	$13,498	0.3144	$100,828	$31,699
17	$0	$87,330	$13,498	0.2925	$100,828	$29,488
18	$0	$87,330	$13,498	0.2720	$100,828	$27,430
19	$0	$87,330	$13,498	0.2531	$100,828	$25,517
20	$0	$87,330	$13,498	0.2354	$100,828	$23,736
21	$0	$0	$13,498	0.2190	$13,498	$2,956
22	$0	$0	$13,498	0.2037	$13,498	$2,750
23	$0	$0	$13,498	0.1895	$13,498	$2,558
24	$0	$0	$13,498	0.1763	$13,498	$2,379
25	$0	$0	$13,498	0.1640	$13,498	$2,213
26	$0	$0	$13,498	0.1525	$13,498	$2,059
27	$0	$0	$13,498	0.1419	$13,498	$1,915
28	$0	$0	$13,498	0.1320	$13,498	$1,782
29	$0	$0	$0	0.1228	$0	$0
30	$0	$0	$0	0.1142	$0	$0
	$1,156,000	**$1,858,278**	**$377,944**			**$2,259,075**

Plume A - Off Base, Exsitu - with 400 gpm Treatment System ***$2,300,000***

PRESENT WORTH CALCULATIONS

Plume A - Off Base, Exsitu - without 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$447,989	$0	$0	1.0000	$447,989	$447,989
1	$0	$9,802	$13,498	0.9302	$23,300	$21,675
2	$0	$9,802	$13,498	0.8653	$23,300	$20,163
3	$0	$9,802	$13,498	0.8050	$23,300	$18,756
4	$0	$9,802	$13,498	0.7488	$23,300	$17,447
5	$0	$47,026	$13,498	0.6966	$60,524	$42,159
6	$0	$9,802	$13,498	0.6480	$23,300	$15,098
7	$0	$9,802	$13,498	0.6028	$23,300	$14,044
8	$0	$9,802	$13,498	0.5607	$23,300	$13,065
9	$0	$9,802	$13,498	0.5216	$23,300	$12,153
10	$0	$47,026	$13,498	0.4852	$60,524	$29,366
11	$0	$9,802	$13,498	0.4513	$23,300	$10,516
12	$0	$9,802	$13,498	0.4199	$23,300	$9,783
13	$0	$9,802	$13,498	0.3906	$23,300	$9,100
14	$0	$9,802	$13,498	0.3633	$23,300	$8,465
15	$0	$47,026	$13,498	0.3380	$60,524	$20,455
16	$0	$9,802	$13,498	0.3144	$23,300	$7,325
17	$0	$9,802	$13,498	0.2925	$23,300	$6,814
18	$0	$9,802	$13,498	0.2720	$23,300	$6,339
19	$0	$9,802	$13,498	0.2531	$23,300	$5,897
20	$0	$9,802	$13,498	0.2354	$23,300	$5,485
21	$0	$9,802	$13,498	0.2190	$23,300	$5,103
22	$0	$0	$13,498	0.2037	$13,498	$2,750
23	$0	$0	$13,498	0.1895	$13,498	$2,558
24	$0	$0	$13,498	0.1763	$13,498	$2,379
25	$0	$0	$13,498	0.1640	$13,498	$2,213
26	$0	$0	$13,498	0.1525	$13,498	$2,059
27	$0	$0	$13,498	0.1419	$13,498	$1,915
28	$0	$0	$13,498	0.1320	$13,498	$1,782
29	$0	$0	$0	0.1228	$0	$0
30	$0	$0	$0	0.1142	$0	$0
	$447,989	**$317,523**	**$377,944**			**$762,854**

Plume A - Off Base, Exsitu - without 400 gpm Treatment System ***$800,000***

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$1,524**

   Assume one sample semiannually until system shutdown
   Assume 1.2 samples/well each sampling event (includes QA samples)
   Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
   Assume 5 existing groundwater monitoring wells for sampling
   Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$1,920**

   Assume rate for 2 sampling technicians @ $48 /hour/technician
   Assume 2 hours/well/sampling event for sampling, shipping, etc.
   Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$625**

   Assume rental of sampling equipment, shipping, etc. @ $250/day
   Assume 5 existing groundwater monitoring wells
   Assume 2 hours per well for sampling
   Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

   Assume 1 man-week per sampling event
   Assume chargeout rate for 1 - Validation Chemist @ $67/hour
   Assume 2 sample events/year

TOTAL MONITORING COSTS **$9,429**

PRESENT WORTH CALCULATIONS

ANNUAL DISCOUNT RATE = 7.5%

YEAR	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$0	1.0000	$0	$0
1	$9,429	0.9302	$9,429	$8,771
2	$9,429	0.8653	$9,429	$8,159
3	$9,429	0.8050	$9,429	$7,590
4	$9,429	0.7488	$9,429	$7,060
5	$9,429	0.6966	$9,429	$6,568
6	$9,429	0.6480	$9,429	$6,110
7	$9,429	0.6028	$9,429	$5,683
8	$9,429	0.5607	$9,429	$5,287
9	$9,429	0.5216	$9,429	$4,918
10	$9,429	0.4852	$9,429	$4,575
11	$9,429	0.4513	$9,429	$4,256
12	$9,429	0.4199	$9,429	$3,959
13	$9,429	0.3906	$9,429	$3,683
14	$9,429	0.3633	$9,429	$3,426
15	$9,429	0.3380	$9,429	$3,187
16	$9,429	0.3144	$9,429	$2,964
17	$9,429	0.2925	$9,429	$2,758
18	$9,429	0.2720	$9,429	$2,565
19	$9,429	0.2531	$9,429	$2,386
20	$9,429	0.2354	$9,429	$2,220
21	$9,429	0.2190	$9,429	$2,065
22	$9,429	0.2037	$9,429	$1,921
23	$9,429	0.1895	$9,429	$1,787
24	$9,429	0.1763	$9,429	$1,662
25	$9,429	0.1640	$9,429	$1,546
26	$9,429	0.1525	$9,429	$1,438
27	$9,429	0.1419	$9,429	$1,338
28	$9,429	0.1320	$9,429	$1,245
29	$0	0.1228	$0	$0
30	$0	0.1142	$0	$0
	$264,012			**$109,125**

Plume D - Source Area, Natural Attenuation ***$110,000***

CAPITAL COSTS

1. Bioremediation Extraction Well Installation **$53,148**

A. Drilling $36,000

Assume Drilling costs at			$150	per linear foot	
Assume	6	wells at an average depth of		40	ft
Total	6	wells		240	linear feet

B. Pump Installation $9,306

Assume Installation technicians @			$48	/hour/technician	
Assume	16	hours per well for pump installation			
6 pumps at	$788	each =	$4,728		
16 hrs/well at	$48	/hr =	$763	per well	
6 wells at	$763	/well =	$4,578	installation	

C. Fencing (assume each well enclosed by 20 ft by 20 ft fence with one 12 ft gate) $7,842

68 linear feet of fence per well at	$10.28	/lf =	$699	
1 12 ft gates per well at	$608	ea =	$608	
		Subtotal =	$1,307	
6 wells at	$1,307	/well =	$7,842	

2. Bioremediation Injection Well Installation **$116,913**

A. Drilling $96,000

Assume Drilling costs at			$150	per linear foot	
Assume	16	wells at an average depth of		40	ft
Total	16	wells		640	linear feet

B. Fencing (assume each well enclosed by 20 ft by 20 ft fence with one 12 ft gate) $20,913

68 linear feet of fence per well at	$10.28	/lf =	$699	
1 12 ft gates per well at	$608	ea =	$608	
		Subtotal =	$1,307	
16 wells at	$1,307	/well =	$20,913	

4. Pipe Installation (from extraction & injection point to header) **$76,928**

A. HDPE Pipe $45,728

Pipe I.D., Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Unit Cost Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
Ext 2"	3,340	167	$4.64	$1.37	$21,095
Rtn 2"	3,900	195	$4.64	$1.37	$24,632
			Subtotal		$45,728

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

B. Electrical and Instrumentation $31,200

Assume	$3,000	per well to install cable, conduit, and handholes			
6 wells at	$3,000	per well =	$18,000		
Assume	$600	per well to install valves and flow elements			
22 wells at	$600	per well =	$13,200		

5. Treatment System (Bioremediation) **$99,069**

A. Treatment/Storage/Office Building $18,180

Assume a 20 ft x 20 ft building to house the each bioremediation treatment system

Concrete Foundation	15 CY (20ft x 20ft x 1 ft thick)			
Excavation	15 CY at	$3.25 /CY =	$49	
Compaction	15 CY at	$2.43 /CY =	$36	
Placement	15 CY at	$139.68 /CY =	$2,095	
Pre-Engineered Structure	400 square ft			
Including Building, Insulation, HVAC unit, Electrical, and Lighting.				
Assume	$40.00 /square ft =	$16,000		

B. Power to site $28,446

	Materials	Installation	Subtotal
Oil Filled Pad Mounted 112.5 KVA Transformer	$14,069	$426	$14,495
Watthour-meter and current transformers	$1,500	$500	$2,000
600A Main Circuit, breaker distribution	$10,451	$1,500	$11,951

C. In Situ Bioremediation Equipment $46,785

2,000 gallon H20 holding tank		$1,570
27.5 gpm pump		$1,295
1,000 gallon Methanol holding tank		$996
Metering pump		$1,627
Skid, tank penetrations, and delivery		$3,500
Braided Hose		$187
Cost of PLC		$5,942
Installation of PLC		$1,188.40
Programming of PLC		
(assume one engineer and one technician for 6 weeks per system)		
$54 /hr for	6 weeks =	$12,960
$48 /hr for	6 weeks =	$11,520
Flow measuring and control devices		$6,000
Assume $5,000 for all valves and flow devices		
Labor $1,000 (assumed at 20% of capital)		

D. Fencing $5,657

Assume each In-Situ Bioremediation system enclosed by 60 bt by 60 ft fence with two 12 ft gate

432 linear feet of fence at	$10.28 /lf =	$4,441
2 12 ft gates at	$608 ea =	$1,216

6. Treatment System (80 gpm UV/OX) **$332,600**

Based on a ratio of flow rates relative to the cost of a 400 GPM system $332,600

System flow =	80 gpm	
Cost of	400 gpm system =	$1,663,000
Cost of the	80 gpm system =	$332,600

7. Testing **$12,240**

Assume 4 technicians and 2 engineers for 3 weeks to test the system

4 Technicians at	$48 /hr for	3 weeks =	$5,760	
2 Engineers at	$54 /hr for	3 weeks =	$6,480	

8. Implementation Costs **$132,570**

Assume Implementation costs at 37% of Capital Costs
Includes Permitting and legal, Services During Construction, Health and Safety,
Report preparation, and engineering design costs.

TOTAL CAPITAL COSTS

Without Treatment System		With Treatment System	
Subtotal (ST)	**$490,868**	Subtotal (ST)	**$823,000**
Overhead and Profit @ 15.5%	**$76,000**	Overhead and Profit @ 15.5%	**$128,000**
Mob/Bond/Insur @ 5% of ST	**$25,000**	Mob/Bond/Insur @ 5% of ST	**$41,000**
Contingency @ 10% of ST	**$49,000**	Contingency @ 10% of ST	**$82,000**
Total	**$640,868**	Total	**$1,074,000**

O & M COSTS

1. Electrical Costs **$2,995**

Extraction System:

Assume	5.5	HP pump (Bioremediation system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation **$118,787**

A. Labor and Maintenance $62,022

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	80 gpm	
Cost of	400 gpm system =	$310,111
Cost of the	80 gpm system =	$62,022

B. Treatment System Influent and Effluent Water Monitoring $3,725

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	80 gpm	
Cost of	400 gpm system =	$18,624
Cost of the	80 gpm system =	$3,725

C. Insitu Bio System Operation $53,040

Assume 1 technician and 1 engineer quarter time to operate the system

1 Technician at	$48 /hr for	13 weeks =	$24,960
1 Engineer at	$54 /hr for	13 weeks =	$28,080

3. Extraction Well Pump Replacement **$9,306**

Assume extraction pumps will require replacement every 5 years

Plume D - Source Area, In-Situ

Assume Installation technicians @ $48 /hour/technician
Assume 16 hours per well for pump installation

6 pumps at	$788	each =	$4,728	
16 hrs/well at	$48	/hr =	$763	per well
6 wells at	$763	/well =	$4,578	installation

Total O&M With Treatment System	**$121,782**
O & M with 5 year Replacement	**$131,088**
Total O&M Without Treatment System	**$56,035**
O & M with 5 year Replacement	**$65,341**

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$1,524**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 5 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$1,920**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$625**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 5 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$9,429**

PRESENT WORTH CALCULATIONS

Plume D - Source Area, In-Situ Treatment - with 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$1,074,000	$0	$0	1.0000	$1,074,000	$1,074,000
1	$0	$121,782	$9,429	0.9302	$131,211	$122,057
2	$0	$121,782	$9,429	0.8653	$131,211	$113,541
3	$0	$121,782	$9,429	0.8050	$131,211	$105,620
4	$0	$121,782	$9,429	0.7488	$131,211	$98,251
5	$0	$131,088	$9,429	0.6966	$140,517	$97,879
6	$0	$121,782	$9,429	0.6480	$131,211	$85,020
7	$0	$121,782	$9,429	0.6028	$131,211	$79,088
8	$0	$121,782	$9,429	0.5607	$131,211	$73,570
9	$0	$121,782	$9,429	0.5216	$131,211	$68,438
10	$0	$131,088	$9,429	0.4852	$140,517	$68,178
11	$0	$121,782	$9,429	0.4513	$131,211	$59,221
12	$0	$121,782	$9,429	0.4199	$131,211	$55,090
13	$0	$121,782	$9,429	0.3906	$131,211	$51,246
14	$0	$121,782	$9,429	0.3633	$131,211	$47,671
15	$0	$131,088	$9,429	0.3380	$140,517	$47,490
16	$0	$121,782	$9,429	0.3144	$131,211	$41,251
17	$0	$0	$9,429	0.2925	$9,429	$2,758
18	$0	$0	$9,429	0.2720	$9,429	$2,565
19	$0	$0	$9,429	0.2531	$9,429	$2,386
20	$0	$0	$9,429	0.2354	$9,429	$2,220
21	$0	$0	$9,429	0.2190	$9,429	$2,065
22	$0	$0	$9,429	0.2037	$9,429	$1,921
23	$0	$0	$9,429	0.1895	$9,429	$1,787
24	$0	$0	$0	0.1763	$0	$0
25	$0	$0	$0	0.1640	$0	$0
26	$0	$0	$0	0.1525	$0	$0
27	$0	$0	$0	0.1419	$0	$0
28	$0	$0	$0	0.1320	$0	$0
29	$0	$0	$0	0.1228	$0	$0
30	$0	$0	$0	0.1142	$0	$0
	$1,074,000	$1,976,434	$216,867			$2,303,312

Plume D - Source Area, In-Situ Treatment ***$2,300,000***

PRESENT WORTH CALCULATIONS

Plume D - Source Area, In-Situ Treatment - without 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$640,868	$0	$0	1.0000	$640,868	$640,868
1	$0	$56,035	$9,429	0.9302	$65,464	$60,897
2	$0	$56,035	$9,429	0.8653	$65,464	$56,648
3	$0	$56,035	$9,429	0.8050	$65,464	$52,696
4	$0	$56,035	$9,429	0.7488	$65,464	$49,020
5	$0	$65,341	$9,429	0.6966	$74,770	$52,082
6	$0	$56,035	$9,429	0.6480	$65,464	$42,418
7	$0	$56,035	$9,429	0.6028	$65,464	$39,459
8	$0	$56,035	$9,429	0.5607	$65,464	$36,706
9	$0	$56,035	$9,429	0.5216	$65,464	$34,145
10	$0	$65,341	$9,429	0.4852	$74,770	$36,278
11	$0	$56,035	$9,429	0.4513	$65,464	$29,547
12	$0	$56,035	$9,429	0.4199	$65,464	$27,485
13	$0	$56,035	$9,429	0.3906	$65,464	$25,568
14	$0	$56,035	$9,429	0.3633	$65,464	$23,784
15	$0	$65,341	$9,429	0.3380	$74,770	$25,270
16	$0	$56,035	$9,429	0.3144	$65,464	$20,581
17	$0	$0	$9,429	0.2925	$9,429	$2,758
18	$0	$0	$9,429	0.2720	$9,429	$2,565
19	$0	$0	$9,429	0.2531	$9,429	$2,386
20	$0	$0	$9,429	0.2354	$9,429	$2,220
21	$0	$0	$9,429	0.2190	$9,429	$2,065
22	$0	$0	$9,429	0.2037	$9,429	$1,921
23	$0	$0	$9,429	0.1895	$9,429	$1,787
24	$0	$0	$0	0.1763	$0	$0
25	$0	$0	$0	0.1640	$0	$0
26	$0	$0	$0	0.1525	$0	$0
27	$0	$0	$0	0.1419	$0	$0
28	$0	$0	$0	0.1320	$0	$0
29	$0	$0	$0	0.1228	$0	$0
30	$0	$0	$0	0.1142	$0	$0
	$640,868	**$924,481**	**$216,867**			**$1,269,152**

Plume D - Source Area, In-Situ Treatment ***$1,300,000***

APITAL COSTS

1. Extraction Well Installation **$70,864**

A. Drilling $48,000

Assume Drilling costs at $150 per linear foot
Assume 8 wells at an average depth of 40 ft
Total 8 wells 320 linear feet

B. Pump Installation $12,408

Assume Installation technicians @ $48 /hour/technician
Assume 16 hours per well for pump installation
8 pumps at $788 each = $6,304
16 hrs/well at $48 /hr = $763 per well
8 wells at $763 /well = $6,104 installation

C. Fencing (assume each well enclosed by 20 ft by 20 ft fence with one 12 ft gate) $10,456

68 linear feet of fence per well at	$10.28	/lf =	$699
1 12 ft gates per well at	$608	ea =	$608
		Subtotal =	$1,307

8 wells at $1,307 /well = $10,456

2. Extraction Pipe Installation (from extraction point to header) **$55,833**

A. HDPE Pipe $27,033

Pipe I.D., Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Unit Cost Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
2	4,280	214	$4.64	$1.37	$27,033
			Subtotal		$27,033

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

B. Electrical and Instrumentation $28,800

Assume $3,000 per pump station to install cable, conduit, and handholes
8 wells at $3,000 per station $24,000

Assume $600 per pump station to install valves and flow elements
8 wells at $600 per station $4,800

3. Treatment System (34 gpm UV/OX) **$141,355**

A. Treatment System $141,355

Based on a ratio of flow rates relative to the cost of a 400 GPM system
System flow = 34 gpm
Cost of 400 gpm system = $1,663,000
Cost of the 34 gpm system = $141,355

Plume D - Source Area, Exsitu

TOTAL CAPITAL COSTS

Without Treatment System		With Treatment System	
Subtotal (ST)	**$126,697**	Subtotal (ST)	**$268,000**
Overhead and Profit @ 15.5%	**$20,000**	Overhead and Profit @ 15.5%	**$42,000**
Mob/Bond/Insur @ 5% of ST	**$6,000**	Mob/Bond/Insur @ 5% of ST	**$13,000**
Contingency @ 10% of ST	**$13,000**	Contingency @ 10% of ST	**$27,000**
Total	**$165,697**	Total	**$350,000**

O & M COSTS

1. Electrical Costs **$6,535**

Extraction System:

Assume	12	HP pump (12 GPM system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation **$27,480**

A. Labor and Maintenance $25,897

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	34	gpm	
Cost of	400	gpm system =	$304,666
Cost of the	34	gpm system =	$25,897

B. Treatment System Influent and Effluent Water Monitoring $1,583

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	34	gpm	
Cost of	400	gpm system =	$18,624
Cost of the	34	gpm system =	$1,583

3. Extraction Trench Pump Replacement **$7,067**

Assume extraction pumps will require replacement every 5 years

Assume Installation technicians @			$48	/hour/technician
Assume	16	hours per well for pump installation		
8 pumps at	$788	each =	$6,304	
16 hrs/pump at	$48	/hr =	$763	per pump

Total O&M With Treatment System	**$34,015**
O & M with 5 year Replacement	**$41,082**
Total O&M Without Treatment System	**$6,535**
O & M with 5 year Replacement	**$13,602**

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$1,524**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)

Plume D - Source Area, Exsitu

Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 5 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$1,920**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$625**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 5 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$9,429**

PRESENT WORTH CALCULATIONS

Plume D - Source Area, Exsitu - with 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$350,000	$0	$0	1.0000	$350,000	$350,000
1	$0	$34,015	$9,429	0.9302	$43,444	$40,413
2	$0	$34,015	$9,429	0.8653	$43,444	$37,593
3	$0	$34,015	$9,429	0.8050	$43,444	$34,970
4	$0	$34,015	$9,429	0.7488	$43,444	$32,531
5	$0	$41,082	$9,429	0.6966	$50,511	$35,184
6	$0	$34,015	$9,429	0.6480	$43,444	$28,150
7	$0	$34,015	$9,429	0.6028	$43,444	$26,186
8	$0	$34,015	$9,429	0.5607	$43,444	$24,359
9	$0	$34,015	$9,429	0.5216	$43,444	$22,659
10	$0	$41,082	$9,429	0.4852	$50,511	$24,507
11	$0	$34,015	$9,429	0.4513	$43,444	$19,608
12	$0	$34,015	$9,429	0.4199	$43,444	$18,240
13	$0	$34,015	$9,429	0.3906	$43,444	$16,967
14	$0	$34,015	$9,429	0.3633	$43,444	$15,784
15	$0	$41,082	$9,429	0.3380	$50,511	$17,071
16	$0	$34,015	$9,429	0.3144	$43,444	$13,658
17	$0	$34,015	$9,429	0.2925	$43,444	$12,705
18	$0	$34,015	$9,429	0.2720	$43,444	$11,819
19	$0	$34,015	$9,429	0.2531	$43,444	$10,994
20	$0	$41,082	$9,429	0.2354	$50,511	$11,891
21	$0	$34,015	$9,429	0.2190	$43,444	$9,514
22	$0	$34,015	$9,429	0.2037	$43,444	$8,850
23	$0	$34,015	$9,429	0.1895	$43,444	$8,232
24	$0	$0	$0	0.1763	$0	$0
25	$0	$0	$0	0.1640	$0	$0
26	$0	$0	$0	0.1525	$0	$0
27	$0	$0	$0	0.1419	$0	$0
28	$0	$0	$0	0.1320	$0	$0
29	$0	$0	$0	0.1228	$0	$0
30	$0	$0	$0	0.1142	$0	$0
	$350,000	**$810,603**	**$216,867**			**$831,885**

Plume D - Source Area, Exsitu ***$800,000***

PRESENT WORTH CALCULATIONS

Plume D - Source Area, Exsitu - without 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$165,697	$0	$0	1.0000	$165,697	$165,697
1	$0	$6,535	$9,429	0.9302	$15,964	$14,850
2	$0	$6,535	$9,429	0.8653	$15,964	$13,814
3	$0	$6,535	$9,429	0.8050	$15,964	$12,850
4	$0	$6,535	$9,429	0.7488	$15,964	$11,954
5	$0	$13,602	$9,429	0.6966	$23,031	$16,042
6	$0	$6,535	$9,429	0.6480	$15,964	$10,344
7	$0	$6,535	$9,429	0.6028	$15,964	$9,622
8	$0	$6,535	$9,429	0.5607	$15,964	$8,951
9	$0	$6,535	$9,429	0.5216	$15,964	$8,327
10	$0	$13,602	$9,429	0.4852	$23,031	$11,174
11	$0	$6,535	$9,429	0.4513	$15,964	$7,205
12	$0	$6,535	$9,429	0.4199	$15,964	$6,703
13	$0	$6,535	$9,429	0.3906	$15,964	$6,235
14	$0	$6,535	$9,429	0.3633	$15,964	$5,800
15	$0	$13,602	$9,429	0.3380	$23,031	$7,784
16	$0	$6,535	$9,429	0.3144	$15,964	$5,019
17	$0	$6,535	$9,429	0.2925	$15,964	$4,669
18	$0	$6,535	$9,429	0.2720	$15,964	$4,343
19	$0	$6,535	$9,429	0.2531	$15,964	$4,040
20	$0	$13,602	$9,429	0.2354	$23,031	$5,422
21	$0	$6,535	$9,429	0.2190	$15,964	$3,496
22	$0	$6,535	$9,429	0.2037	$15,964	$3,252
23	$0	$6,535	$9,429	0.1895	$15,964	$3,025
24	$0	$0	$0	0.1763	$0	$0
25	$0	$0	$0	0.1640	$0	$0
26	$0	$0	$0	0.1525	$0	$0
27	$0	$0	$0	0.1419	$0	$0
28	$0	$0	$0	0.1320	$0	$0
29	$0	$0	$0	0.1228	$0	$0
30	$0	$0	$0	0.1142	$0	$0
	$165,697	**$178,572**	**$216,867**			**$350,618**

Plume D - Source Area, Exsitu ***$400,000***

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$1,524**

   Assume one sample semiannually until system shutdown
   Assume 1.2 samples/well each sampling event (includes QA samples)
   Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
   Assume 5 existing groundwater monitoring wells for sampling
   Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$1,920**

   Assume rate for 2 sampling technicians @ $48 /hour/technician
   Assume 2 hours/well/sampling event for sampling, shipping, etc.
   Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$625**

   Assume rental of sampling equipment, shipping, etc. @ $250/day
   Assume 5 existing groundwater monitoring wells
   Assume 2 hours per well for sampling
   Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

   Assume 1 man-week per sampling event
   Assume chargeout rate for 1 - Validation Chemist @ $67/hour
   Assume 2 sample events/year

TOTAL MONITORING COSTS **$9,429**

Plume D - Perimeter, Natural Attenuation

PRESENT WORTH CALCULATIONS

ANNUAL DISCOUNT RATE = 7.5%

YEAR	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$0	1.0000	$0	$0
1	$9,429	0.9302	$9,429	$8,771
2	$9,429	0.8653	$9,429	$8,159
3	$9,429	0.8050	$9,429	$7,590
4	$9,429	0.7488	$9,429	$7,060
5	$9,429	0.6966	$9,429	$6,568
6	$9,429	0.6480	$9,429	$6,110
7	$9,429	0.6028	$9,429	$5,683
8	$9,429	0.5607	$9,429	$5,287
9	$9,429	0.5216	$9,429	$4,918
10	$9,429	0.4852	$9,429	$4,575
11	$9,429	0.4513	$9,429	$4,256
12	$9,429	0.4199	$9,429	$3,959
13	$9,429	0.3906	$9,429	$3,683
14	$9,429	0.3633	$9,429	$3,426
15	$9,429	0.3380	$9,429	$3,187
16	$9,429	0.3144	$9,429	$2,964
17	$9,429	0.2925	$9,429	$2,758
18	$9,429	0.2720	$9,429	$2,565
19	$9,429	0.2531	$9,429	$2,386
20	$9,429	0.2354	$9,429	$2,220
21	$9,429	0.2190	$9,429	$2,065
22	$9,429	0.2037	$9,429	$1,921
23	$9,429	0.1895	$9,429	$1,787
24	$9,429	0.1763	$9,429	$1,662
25	$9,429	0.1640	$9,429	$1,546
26	$9,429	0.1525	$9,429	$1,438
27	$9,429	0.1419	$9,429	$1,338
28	$9,429	0.1320	$9,429	$1,245
29	$0	0.1228	$0	$0
30	$0	0.1142	$0	$0
	$264,012			**$109,125**

Plume D - Perimeter, Natural Attenuation ***$110,000***

CAPITAL COSTS

1. Extraction Well Installation **$283,457**

A. Drilling $192,000

Assume Drilling costs at			$150	per linear foot	
Assume	32	wells at an average depth of		40	ft
Total	32	wells		1,280	linear feet

B. Pump Installation $49,632

Assume Installation technicians @			$48	/hour/technician	
Assume	16	hours per well for pump installation			
32	pumps at	$788	each =	$25,216	
16	hrs/well at	$48	/hr =	$763	per well
32	wells at	$763	/well =	$24,416	installation

C. Fencing (assume each well enclosed by 20 ft by 20 ft fence with one 12 ft gate) $41,825

68	linear feet of fence per well at	$10.28	/lf =	$699
1	12 ft gates per well at	$608	ea =	$608
			Subtotal =	$1,307

32	wells at	$1,307	/well =	$41,825

2. Extraction Pipe Installation (from extraction point to header) **$173,939**

A. HDPE Pipe $58,739

Pipe I.D., Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Unit Cost Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
2	9,300	465	$4.64	$1.37	$58,739
			Subtotal		$58,739

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

B. Electrical and Instrumentation $115,200

Assume	$3,000	per pump station to install cable, conduit, and handholes		
32	wells at	$3,000	per station	$96,000
Assume	$600	per pump station to install valves and flow elements		
32	wells at	$600	per station	$19,200

3. Treatment System (70 gpm UV/OX) **$291,025**

A. Treatment System $291,025

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	70	gpm	
Cost of	400	gpm system =	$1,663,000
Cost of the	70	gpm system =	$291,025

Plume D - Perimeter, Exsitu

TOTAL CAPITAL COSTS

Without Treatment System		With Treatment System	
Subtotal (ST)	**$457,396**	Subtotal (ST)	**$748,000**
Overhead and Profit @ 15.5%	**$71,000**	Overhead and Profit @ 15.5%	**$116,000**
Mob/Bond/Insur @ 5% of ST	**$23,000**	Mob/Bond/Insur @ 5% of ST	**$37,000**
Contingency @ 10% of ST	**$46,000**	Contingency @ 10% of ST	**$75,000**
Total	**$597,396**	Total	**$976,000**

O & M COSTS

1. Electrical Costs **$16,337**

Extraction System:

Assume	30	HP pump (70 GPM system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation **$57,529**

A. Labor and Maintenance $54,269

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	70	gpm	
Cost of	400	gpm system =	$310,111
Cost of the	70	gpm system =	$54,269

B. Treatment System Influent and Effluent Water Monitoring $3,259

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	70	gpm	
Cost of	400	gpm system =	$18,624
Cost of the	70	gpm system =	$3,259

3. Extraction Trench Pump Replacement **$25,979**

Assume extraction pumps will require replacement every 5 years

Assume Installation technicians @			$48	/hour/technician
Assume	16	hours per well for pump installation		
32 pumps at	$788	each =	$25,216	
16 hrs/pump at	$48	/hr =	$763	per pump

Total O&M With Treatment System	**$73,866**
O & M with 5 year Replacement	**$99,845**
Total O&M Without Treatment System	**$16,337**
O & M with 5 year Replacement	**$42,316**

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$1,524**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)

Plume D - Perimeter, Exsitu

Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 5 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$1,920**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$625**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 5 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$9,429**

PRESENT WORTH CALCULATIONS

Plume D - Perimeter, Exsitu - with 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$976,000	$0	$0	1.0000	$976,000	$976,000
1	$0	$73,866	$9,429	0.9302	$83,295	$77,484
2	$0	$73,866	$9,429	0.8653	$83,295	$72,078
3	$0	$73,866	$9,429	0.8050	$83,295	$67,049
4	$0	$73,866	$9,429	0.7488	$83,295	$62,371
5	$0	$99,845	$9,429	0.6966	$109,274	$76,116
6	$0	$73,866	$9,429	0.6480	$83,295	$53,972
7	$0	$73,866	$9,429	0.6028	$83,295	$50,207
8	$0	$73,866	$9,429	0.5607	$83,295	$46,704
9	$0	$73,866	$9,429	0.5216	$83,295	$43,445
10	$0	$99,845	$9,429	0.4852	$109,274	$53,019
11	$0	$73,866	$9,429	0.4513	$83,295	$37,595
12	$0	$73,866	$9,429	0.4199	$83,295	$34,972
13	$0	$73,866	$9,429	0.3906	$83,295	$32,532
14	$0	$73,866	$9,429	0.3633	$83,295	$30,262
15	$0	$99,845	$9,429	0.3380	$109,274	$36,931
16	$0	$73,866	$9,429	0.3144	$83,295	$26,187
17	$0	$73,866	$9,429	0.2925	$83,295	$24,360
18	$0	$73,866	$9,429	0.2720	$83,295	$22,660
19	$0	$73,866	$9,429	0.2531	$83,295	$21,079
20	$0	$99,845	$9,429	0.2354	$109,274	$25,725
21	$0	$73,866	$9,429	0.2190	$83,295	$18,241
22	$0	$73,866	$9,429	0.2037	$83,295	$16,968
23	$0	$73,866	$9,429	0.1895	$83,295	$15,784
24	$0	$0	$0	0.1763	$0	$0
25	$0	$0	$0	0.1640	$0	$0
26	$0	$0	$0	0.1525	$0	$0
27	$0	$0	$0	0.1419	$0	$0
28	$0	$0	$0	0.1320	$0	$0
29	$0	$0	$0	0.1228	$0	$0
30	$0	$0	$0	0.1142	$0	$0
	$976,000	**$1,802,836**	**$216,867**			**$1,921,741**

Plume D - Perimeter, Exsitu ***$1,900,000***

PRESENT WORTH CALCULATIONS

Plume D - Perimeter, Exsitu - without 400 gpm Treatment system

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$597,396	$0	$0	1.0000	$597,396	$597,396
1	$0	$16,337	$9,429	0.9302	$25,766	$23,969
2	$0	$16,337	$9,429	0.8653	$25,766	$22,297
3	$0	$16,337	$9,429	0.8050	$25,766	$20,741
4	$0	$16,337	$9,429	0.7488	$25,766	$19,294
5	$0	$42,316	$9,429	0.6966	$51,745	$36,044
6	$0	$16,337	$9,429	0.6480	$25,766	$16,696
7	$0	$16,337	$9,429	0.6028	$25,766	$15,531
8	$0	$16,337	$9,429	0.5607	$25,766	$14,447
9	$0	$16,337	$9,429	0.5216	$25,766	$13,439
10	$0	$42,316	$9,429	0.4852	$51,745	$25,107
11	$0	$16,337	$9,429	0.4513	$25,766	$11,629
12	$0	$16,337	$9,429	0.4199	$25,766	$10,818
13	$0	$16,337	$9,429	0.3906	$25,766	$10,063
14	$0	$16,337	$9,429	0.3633	$25,766	$9,361
15	$0	$42,316	$9,429	0.3380	$51,745	$17,488
16	$0	$16,337	$9,429	0.3144	$25,766	$8,101
17	$0	$16,337	$9,429	0.2925	$25,766	$7,535
18	$0	$16,337	$9,429	0.2720	$25,766	$7,010
19	$0	$16,337	$9,429	0.2531	$25,766	$6,521
20	$0	$42,316	$9,429	0.2354	$51,745	$12,182
21	$0	$16,337	$9,429	0.2190	$25,766	$5,643
22	$0	$16,337	$9,429	0.2037	$25,766	$5,249
23	$0	$16,337	$9,429	0.1895	$25,766	$4,883
24	$0	$0	$0	0.1763	$0	$0
25	$0	$0	$0	0.1640	$0	$0
26	$0	$0	$0	0.1525	$0	$0
27	$0	$0	$0	0.1419	$0	$0
28	$0	$0	$0	0.1320	$0	$0
29	$0	$0	$0	0.1228	$0	$0
30	$0	$0	$0	0.1142	$0	$0
	$597,396	**$479,676**	**$216,867**			**$921,442**

Plume D - Perimeter, Exsitu ***$900,000***

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$1,524**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 5 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110 /sample
Total (including 15% CLP) =	$127 /sample event

2. Labor (for Groundwater Well Sampling) **$1,920**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$625**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 5 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$9,429**

Plume D - Base Perimeter, Natural Attenuation

PRESENT WORTH CALCULATIONS

ANNUAL DISCOUNT RATE = 7.5%

YEAR	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$0	1.0000	$0	$0
1	$9,429	0.9302	$9,429	$8,771
2	$9,429	0.8653	$9,429	$8,159
3	$9,429	0.8050	$9,429	$7,590
4	$9,429	0.7488	$9,429	$7,060
5	$9,429	0.6966	$9,429	$6,568
6	$9,429	0.6480	$9,429	$6,110
7	$9,429	0.6028	$9,429	$5,683
8	$9,429	0.5607	$9,429	$5,287
9	$9,429	0.5216	$9,429	$4,918
10	$9,429	0.4852	$9,429	$4,575
11	$9,429	0.4513	$9,429	$4,256
12	$9,429	0.4199	$9,429	$3,959
13	$9,429	0.3906	$9,429	$3,683
14	$9,429	0.3633	$9,429	$3,426
15	$9,429	0.3380	$9,429	$3,187
16	$9,429	0.3144	$9,429	$2,964
17	$9,429	0.2925	$9,429	$2,758
18	$9,429	0.2720	$9,429	$2,565
19	$9,429	0.2531	$9,429	$2,386
20	$9,429	0.2354	$9,429	$2,220
21	$9,429	0.2190	$9,429	$2,065
22	$9,429	0.2037	$9,429	$1,921
23	$9,429	0.1895	$9,429	$1,787
24	$9,429	0.1763	$9,429	$1,662
25	$9,429	0.1640	$9,429	$1,546
26	$9,429	0.1525	$9,429	$1,438
27	$9,429	0.1419	$9,429	$1,338
28	$9,429	0.1320	$9,429	$1,245
29	$0	0.1228	$0	$0
30	$0	0.1142	$0	$0
	$264,012			**$109,125**

Plume D - Off Base, Natural Attenuation ***$110,000***

Plume D - Base Perimeter, Exsitu

CAPITAL COSTS

1. Collector Trench Installation **$210,660**

Assume Trench costs at $225 /linear foot
Assume 900 linear feet of trench
900 lf at $225 /lf = $202,500
Includes trench and sumps installed at 300 ft intervals

Pump Installation
Assume 4 pump stations

Cost of Pump and Motor =	$1,700
Installation (assumed at 20% of capital)	$340
Subtotal	$2,040

4 pumps at $2,040 each = $8,160

2. Extraction Pipe Installation (from extraction point to header) **$32,716**

A. HDPE Pipe $18,316

Pipe I.D., Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
2	2,900	145	$4.64	$1.37	$18,316
			Subtotal		$18,316

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

B. Electrical and Instrumentation $14,400

Assume $3,000 per pump station to install cable, conduit, and handholes
4 stations at $3,000 per station $12,000

Assume $600 per pump station to install valves and flow elements
4 stations at $600 per station $2,400

3. Treatment System **$0**

A. Treatment System will be an existing system with excess capacity, assume no capital cost. **$0**

TOTAL CAPITAL COSTS

Subtotal (ST)*	**$81,000**
Overhead and Profit @ 15.5%	**$13,000**
Mob/Bond/Insur @ 5% of ST	**$4,000**
Contingency @ 10% of ST	**$8,000**
Total	**$106,000**

* Subtotal is 1/3 of cost to reflect costs being shared by plumes F and I.

O & M COSTS

1. Electrical Costs **$4,901**

Plume D - Base Perimeter, Exsitu

Extraction System:

Assume	9	HP pump (35 GPM system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation **$57,529**

A. Labor and Maintenance $54,269

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	70	gpm	
Cost of	400	gpm system =	$310,111
Cost of the	70	gpm system =	$54,269

B. Treatment System Influent and Effluent Water Monitoring $3,259

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	70	gpm	
Cost of	400	gpm system =	$18,624
Cost of the	70	gpm system =	$3,259

3. Extraction Trench Pump Replacement **$3,915**

Assume extraction pumps will require replacement every 5 years

Assume Installation technicians @ $48 /hour/technician

Assume 16 hours per well for pump installation

4 pumps at	$788	each =	$3,152	
16 hrs/pump at	$48	/hr =	$763	per pump

	Total O&M With Treatment*	**$20,810**
*O&M Costs divided by 3 to reflect sharing with Plumes F & I	O & M with 5 year Replacement	**$22,115**
	Total O&M Without Treatment*	**$1,634**
	O & M with 5 year Replacement	**$5,549**

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$1,524**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 5 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$1,920**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

Plume D - Base Perimeter, Exsitu

3. Rental of Equipment (for Groundwater Well Sampling)	**$625**
Assume rental of sampling equipment, shipping, etc. @ $250/day Assume 5 existing groundwater monitoring wells Assume 2 hours per well for sampling Assume 2 sample events/year	
4. Labor (for Data Analysis and Validation of Groundwater Data)	**$5,360**
Assume 1 man-week per sampling event Assume chargeout rate for 1 - Validation Chemist @ $67/hour Assume 2 sample events/year	
TOTAL MONITORING COSTS	**$9,429**

PRESENT WORTH CALCULATIONS

Plume D - Base Perimeter, Exsitu - with 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$106,000	$0	$0	1.0000	$106,000	$106,000
1	$0	$20,810	$9,429	0.9302	$30,239	$28,129
2	$0	$20,810	$9,429	0.8653	$30,239	$26,167
3	$0	$20,810	$9,429	0.8050	$30,239	$24,341
4	$0	$20,810	$9,429	0.7488	$30,239	$22,643
5	$0	$22,115	$9,429	0.6966	$31,544	$21,972
6	$0	$20,810	$9,429	0.6480	$30,239	$19,594
7	$0	$20,810	$9,429	0.6028	$30,239	$18,227
8	$0	$20,810	$9,429	0.5607	$30,239	$16,955
9	$0	$20,810	$9,429	0.5216	$30,239	$15,772
10	$0	$22,115	$9,429	0.4852	$31,544	$15,305
11	$0	$20,810	$9,429	0.4513	$30,239	$13,648
12	$0	$20,810	$9,429	0.4199	$30,239	$12,696
13	$0	$20,810	$9,429	0.3906	$30,239	$11,810
14	$0	$20,810	$9,429	0.3633	$30,239	$10,986
15	$0	$22,115	$9,429	0.3380	$31,544	$10,661
16	$0	$20,810	$9,429	0.3144	$30,239	$9,507
17	$0	$20,810	$9,429	0.2925	$30,239	$8,843
18	$0	$20,810	$9,429	0.2720	$30,239	$8,226
19	$0	$20,810	$9,429	0.2531	$30,239	$7,653
20	$0	$22,115	$9,429	0.2354	$31,544	$7,426
21	$0	$20,810	$9,429	0.2190	$30,239	$6,622
22	$0	$20,810	$9,429	0.2037	$30,239	$6,160
23	$0	$20,810	$9,429	0.1895	$30,239	$5,730
24	$0	$0	$0	0.1763	$0	$0
25	$0	$0	$0	0.1640	$0	$0
26	$0	$0	$0	0.1525	$0	$0
27	$0	$0	$0	0.1419	$0	$0
28	$0	$0	$0	0.1320	$0	$0
29	$0	$0	$0	0.1228	$0	$0
30	$0	$0	$0	0.1142	$0	$0
	$106,000	**$483,849**	**$216,867**			**$435,074**

Plume D - Base Perimeter, Exsitu ***$400,000***

PRESENT WORTH CALCULATIONS

Plume D - Base Perimeter, Exsitu - without 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$106,000	$0	$0	1.0000	$106,000	$106,000
1	$0	$1,634	$9,429	0.9302	$11,063	$10,291
2	$0	$1,634	$9,429	0.8653	$11,063	$9,573
3	$0	$1,634	$9,429	0.8050	$11,063	$8,905
4	$0	$1,634	$9,429	0.7488	$11,063	$8,284
5	$0	$5,549	$9,429	0.6966	$14,978	$10,433
6	$0	$1,634	$9,429	0.6480	$11,063	$7,168
7	$0	$1,634	$9,429	0.6028	$11,063	$6,668
8	$0	$1,634	$9,429	0.5607	$11,063	$6,203
9	$0	$1,634	$9,429	0.5216	$11,063	$5,770
10	$0	$5,549	$9,429	0.4852	$14,978	$7,267
11	$0	$1,634	$9,429	0.4513	$11,063	$4,993
12	$0	$1,634	$9,429	0.4199	$11,063	$4,645
13	$0	$1,634	$9,429	0.3906	$11,063	$4,321
14	$0	$1,634	$9,429	0.3633	$11,063	$4,019
15	$0	$5,549	$9,429	0.3380	$14,978	$5,062
16	$0	$1,634	$9,429	0.3144	$11,063	$3,478
17	$0	$1,634	$9,429	0.2925	$11,063	$3,235
18	$0	$1,634	$9,429	0.2720	$11,063	$3,010
19	$0	$1,634	$9,429	0.2531	$11,063	$2,800
20	$0	$5,549	$9,429	0.2354	$14,978	$3,526
21	$0	$1,634	$9,429	0.2190	$11,063	$2,423
22	$0	$1,634	$9,429	0.2037	$11,063	$2,254
23	$0	$1,634	$9,429	0.1895	$11,063	$2,096
24	$0	$0	$0	0.1763	$0	$0
25	$0	$0	$0	0.1640	$0	$0
26	$0	$0	$0	0.1525	$0	$0
27	$0	$0	$0	0.1419	$0	$0
28	$0	$0	$0	0.1320	$0	$0
29	$0	$0	$0	0.1228	$0	$0
30	$0	$0	$0	0.1142	$0	$0
	$106,000	**$53,236**	**$216,867**			**$232,423**

Plume D - Base Perimeter, Exsitu ***$200,000***

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$4,572**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 15 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$5,760**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$1,875**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 15 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$17,567**

PRESENT WORTH CALCULATIONS

ANNUAL DISCOUNT RATE = 7.5%

YEAR	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$0	1.0000	$0	$0
1	$17,567	0.9302	$17,567	$16,341
2	$17,567	0.8653	$17,567	$15,201
3	$17,567	0.8050	$17,567	$14,141
4	$17,567	0.7488	$17,567	$13,154
5	$17,567	0.6966	$17,567	$12,236
6	$17,567	0.6480	$17,567	$11,383
7	$17,567	0.6028	$17,567	$10,589
8	$17,567	0.5607	$17,567	$9,850
9	$17,567	0.5216	$17,567	$9,163
10	$17,567	0.4852	$17,567	$8,523
11	$17,567	0.4513	$17,567	$7,929
12	$17,567	0.4199	$17,567	$7,376
13	$17,567	0.3906	$17,567	$6,861
14	$17,567	0.3633	$17,567	$6,382
15	$17,567	0.3380	$17,567	$5,937
16	$17,567	0.3144	$17,567	$5,523
17	$17,567	0.2925	$17,567	$5,138
18	$17,567	0.2720	$17,567	$4,779
19	$17,567	0.2531	$17,567	$4,446
20	$17,567	0.2354	$17,567	$4,136
21	$17,567	0.2190	$17,567	$3,847
22	$17,567	0.2037	$17,567	$3,579
23	$17,567	0.1895	$17,567	$3,329
24	$17,567	0.1763	$17,567	$3,097
25	$17,567	0.1640	$17,567	$2,881
26	$17,567	0.1525	$17,567	$2,680
27	$17,567	0.1419	$17,567	$2,493
28	$17,567	0.1320	$17,567	$2,319
29	$17,567	0.1228	$17,567	$2,157
30	$17,567	0.1142	$17,567	$2,007
	$527,010			**$207,473**

Plume F - Perimeter, Natural Attenuation ***$210,000***

Plume F - Perimeter, Exsitu

CAPITAL COSTS

1. Collector Trench Installation **$210,660**

Assume Trench costs at $225 /linear foot
Assume 900 linear feet of trench
900 lf at $225 /lf = $202,500
Includes trench and sumps installed at 300 ft intervals

Pump Installation
Assume 4 pump stations
Cost of Pump and Motor = $1,700
Installation (assumed at 20% of capital) $340
Subtotal $2,040

4 pumps at $2,040 each = $8,160

2. Extraction Pipe Installation (from extraction point to header) **$32,716**

A. HDPE Pipe $18,316

Pipe I.D., Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
2	2,900	145	$4.64	$1.37	$18,316
				Subtotal	$18,316

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

B. Electrical and Instrumentation $14,400

Assume $3,000 per pump station to install cable, conduit, and handholes
4 stations at $3,000 per station $12,000

Assume $600 per pump station to install valves and flow elements
4 stations at $600 per station $2,400

3. Treatment System **$0**

A. Treatment System will be an existing system with excess capacity, assume no capital cost. $0

TOTAL CAPITAL COSTS

Subtotal (ST)*	**$81,000**
Overhead and Profit @ 15.5%	**$13,000**
Mob/Bond/Insur @ 5% of ST	**$4,000**
Contingency @ 10% of ST	**$8,000**
Total	**$106,000**

* Subtotal is 1/3 of cost to reflect costs being shared by plumes F and I.

O & M COSTS

1. Electrical Costs **$4,901**

Plume F - Perimeter, Exsitu

Extraction System:

Assume	9	HP pump (35 GPM system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation **$57,529**

A. Labor and Maintenance $54,269

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	70	gpm	
Cost of	400	gpm system =	$310,111
Cost of the	70	gpm system =	$54,269

B. Treatment System Influent and Effluent Water Monitoring $3,259

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	70	gpm	
Cost of	400	gpm system =	$18,624
Cost of the	70	gpm system =	$3,259

3. Extraction Trench Pump Replacement **$3,915**

Assume extraction pumps will require replacement every 5 years

Assume Installation technicians @ $48 /hour/technician

Assume 16 hours per well for pump installation

4 pumps at	$788	each =	$3,152
16 hrs/pump at	$48	/hr =	$763 per pump

	Total O&M With Treatment System*	**$20,810**
*O&M Costs divided by 3 to reflect sharing with Plumes F & I	O & M with 5 year Replacement	**$22,115**
	Total O&M Without Treatment System*	**$1,634**
	O & M with 5 year Replacement	**$2,938.74**

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$4,572**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 15 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$5,760**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling)	**$1,875**
Assume rental of sampling equipment, shipping, etc. @ $250/day Assume 15 existing groundwater monitoring wells Assume 2 hours per well for sampling Assume 2 sample events/year	
4. Labor (for Data Analysis and Validation of Groundwater Data)	**$5,360**
Assume 1 man-week per sampling event Assume chargeout rate for 1 - Validation Chemist @ $67/hour Assume 2 sample events/year	
TOTAL MONITORING COSTS	**$17,567**

PRESENT WORTH CALCULATIONS

Plume F - Perimeter, Exsitu - with 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$106,000	$0	$0	1.0000	$106,000	$106,000
1	$0	$20,810	$17,567	0.9302	$38,377	$35,700
2	$0	$20,810	$17,567	0.8653	$38,377	$33,209
3	$0	$20,810	$17,567	0.8050	$38,377	$30,892
4	$0	$20,810	$17,567	0.7488	$38,377	$28,737
5	$0	$22,115	$17,567	0.6966	$39,682	$27,641
6	$0	$20,810	$17,567	0.6480	$38,377	$24,867
7	$0	$20,810	$17,567	0.6028	$38,377	$23,132
8	$0	$20,810	$17,567	0.5607	$38,377	$21,518
9	$0	$20,810	$17,567	0.5216	$38,377	$20,017
10	$0	$22,115	$17,567	0.4852	$39,682	$19,253
11	$0	$20,810	$17,567	0.4513	$38,377	$17,321
12	$0	$20,810	$17,567	0.4199	$38,377	$16,113
13	$0	$20,810	$17,567	0.3906	$38,377	$14,989
14	$0	$20,810	$17,567	0.3633	$38,377	$13,943
15	$0	$22,115	$17,567	0.3380	$39,682	$13,411
16	$0	$20,810	$17,567	0.3144	$38,377	$12,065
17	$0	$20,810	$17,567	0.2925	$38,377	$11,223
18	$0	$20,810	$17,567	0.2720	$38,377	$10,440
19	$0	$20,810	$17,567	0.2531	$38,377	$9,712
20	$0	$20,810	$17,567	0.2354	$38,377	$9,034
21	$0	$0	$17,567	0.2190	$17,567	$3,847
22	$0	$0	$17,567	0.2037	$17,567	$3,579
23	$0	$0	$17,567	0.1895	$17,567	$3,329
24	$0	$0	$17,567	0.1763	$17,567	$3,097
25	$0	$0	$17,567	0.1640	$17,567	$2,881
26	$0	$0	$17,567	0.1525	$17,567	$2,680
27	$0	$0	$17,567	0.1419	$17,567	$2,493
28	$0	$0	$17,567	0.1320	$17,567	$2,319
29	$0	$0	$17,567	0.1228	$17,567	$2,157
30	$0	$0	$17,567	0.1142	$17,567	$2,007
	$106,000	**$420,114**	**$527,010**			**$527,603**

Plume F - Perimeter, Exsitu ***$500,000***

PRESENT WORTH CALCULATIONS

Plume F - Perimeter, Exsitu - without 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$106,000	$0	$0	1.0000	$106,000	$106,000
1	$0	$1,634	$17,567	0.9302	$19,201	$17,861
2	$0	$1,634	$17,567	0.8653	$19,201	$16,615
3	$0	$1,634	$17,567	0.8050	$19,201	$15,456
4	$0	$1,634	$17,567	0.7488	$19,201	$14,378
5	$0	$2,939	$17,567	0.6966	$20,506	$14,283
6	$0	$1,634	$17,567	0.6480	$19,201	$12,441
7	$0	$1,634	$17,567	0.6028	$19,201	$11,573
8	$0	$1,634	$17,567	0.5607	$19,201	$10,766
9	$0	$1,634	$17,567	0.5216	$19,201	$10,015
10	$0	$2,939	$17,567	0.4852	$20,506	$9,949
11	$0	$1,634	$17,567	0.4513	$19,201	$8,666
12	$0	$1,634	$17,567	0.4199	$19,201	$8,062
13	$0	$1,634	$17,567	0.3906	$19,201	$7,499
14	$0	$1,634	$17,567	0.3633	$19,201	$6,976
15	$0	$2,939	$17,567	0.3380	$20,506	$6,930
16	$0	$1,634	$17,567	0.3144	$19,201	$6,036
17	$0	$1,634	$17,567	0.2925	$19,201	$5,615
18	$0	$1,634	$17,567	0.2720	$19,201	$5,224
19	$0	$1,634	$17,567	0.2531	$19,201	$4,859
20	$0	$1,634	$17,567	0.2354	$19,201	$4,520
21	$0	$0	$17,567	0.2190	$17,567	$3,847
22	$0	$0	$17,567	0.2037	$17,567	$3,579
23	$0	$0	$17,567	0.1895	$17,567	$3,329
24	$0	$0	$17,567	0.1763	$17,567	$3,097
25	$0	$0	$17,567	0.1640	$17,567	$2,881
26	$0	$0	$17,567	0.1525	$17,567	$2,680
27	$0	$0	$17,567	0.1419	$17,567	$2,493
28	$0	$0	$17,567	0.1320	$17,567	$2,319
29	$0	$0	$17,567	0.1228	$17,567	$2,157
30	$0	$0	$17,567	0.1142	$17,567	$2,007
	$106,000	**$36,590**	**$527,010**			**$332,111**

Plume F - Perimeter, Exsitu ***$300,000***

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$3,048**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 10 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$3,840**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$1,250**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 10 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

1. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$13,498**

PRESENT WORTH CALCULATIONS

ANNUAL DISCOUNT RATE = 7.5%

YEAR	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$0	1.0000	$0	$0
1	$13,498	0.9302	$13,498	$12,556
2	$13,498	0.8653	$13,498	$11,680
3	$13,498	0.8050	$13,498	$10,865
4	$13,498	0.7488	$13,498	$10,107
5	$13,498	0.6966	$13,498	$9,402
6	$13,498	0.6480	$13,498	$8,746
7	$13,498	0.6028	$13,498	$8,136
8	$0	0.5607	$0	$0
9	$0	0.5216	$0	$0
10	$0	0.4852	$0	$0
11	$0	0.4513	$0	$0
12	$0	0.4199	$0	$0
13	$0	0.3906	$0	$0
14	$0	0.3633	$0	$0
15	$0	0.3380	$0	$0
	$94,486			**$71,494**

Plume H - Perimeter, Natural Attenuation ***$70,000***

Plume H - Perimeter, Exsitu

CAPITAL COSTS

1. Extraction Well Installation **$105,729**

A. Drilling $60,000

Assume Drilling costs at $150 per linear foot
Assume 16 wells at an average depth of 25 ft
Total 16 wells 400 linear feet

B. Pump Installation $24,816

Assume Installation technicians @ $48 /hour/technician
Assume 16 hours per well for pump installation

16 pumps at	$788 each =	$12,608	
16 hrs/well at	$48 /hr =	$763	per well
16 wells at	$763 /well =	$12,208	installation

C. Fencing (assume each well enclosed by 20 ft by 20 ft fence with one 12 ft gate) $20,913

68 linear feet of fence per well at	$10.28 /lf =	$699	
1 12 ft gates per well at	$608 ea =	$608	
	Subtotal =	$1,307	

16 wells at $1,307 /well = $20,913

2. Extraction Pipe Installation (from extraction point to header) **$80,233**

A. HDPE Pipe $22,633

Pipe I.D., Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Unit Cost Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
2	750	38	$4.64	$1.37	$4,737
4	2,350	118	$4.64	$2.61	$17,896
			Subtotal		$22,633

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

B. Electrical and Instrumentation $57,600

Assume $3,000 per pump station to install cable, conduit, and handholes
16 wells at $3,000 per station $48,000

Assume $600 per pump station to install valves and flow elements
16 wells at $600 per station $9,600

3. Treatment System (160 gpm UV/OX) **$665,200**

A. Treatment System $665,200

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	160 gpm	
Cost of	400 gpm system =	$1,663,000
Cost of the	160 gpm system =	$665,200

TOTAL CAPITAL COSTS

Without Treatment system		With Treatment system	
Subtotal (ST)	**$185,962**	Subtotal (ST)	**$851,000**
Overhead and Profit @ 15.5%	**$29,000**	Overhead and Profit @ 15.5%	**$132,000**
Mob/Bond/Insur @ 5% of ST	**$9,000**	Mob/Bond/Insur @ 5% of ST	**$43,000**
Contingency @ 10% of ST	**$19,000**	Contingency @ 10% of ST	**$85,000**
Total	**$242,962**	Total	**$1,111,000**

O & M COSTS

1. Electrical Costs **$9,802**

Extraction System:

Assume	18	HP pump (12 GPM system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation **$131,494**

A. Labor and Maintenance $124,045

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	160 gpm	
Cost of	400 gpm system =	$310,111
Cost of the	160 gpm system =	$124,045

B. Treatment System Influent and Effluent Water Monitoring $7,450

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	160 gpm	
Cost of	400 gpm system =	$18,624
Cost of the	160 gpm system =	$7,450

3. Extraction Trench Pump Replacement **$13,371**

Assume extraction pumps will require replacement every 5 years

Assume Installation technicians @			$48	/hour/technician
Assume	16	hours per well for pump installation		
16 pumps at	$788	each =	$12,608	
16 hrs/pump at	$48	/hr =	$763	per pump

Total O&M With Treatment System	**$141,297**
O & M with 5 year Replacement	**$154,668**
Total O&M Without Treatment System	**$9,802**
O & M with 5 year Replacement	**$23,173**

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$3,048**

Assume one sample semiannually until system shutdown

Plume H - Perimeter, Exsitu

Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 10 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$3,840**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$1,250**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 10 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$13,498**

PRESENT WORTH CALCULATIONS

Plume H - Perimeter, Exsitu - with 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$1,111,000	$0	$0	1.0000	$1,111,000	$1,111,000
1	$0	$141,297	$13,498	0.9302	$154,795	$143,995
2	$0	$141,297	$13,498	0.8653	$154,795	$133,949
3	$0	$141,297	$13,498	0.8050	$154,795	$124,604
4	$0	$141,297	$13,498	0.7488	$154,795	$115,910
5	$0	$141,297	$13,498	0.6966	$154,795	$107,824
6	$0	$0	$13,498	0.6480	$13,498	$8,746
7	$0	$0	$13,498	0.6028	$13,498	$8,136
8	$0	$0	$0	0.5607	$0	$0
9	$0	$0	$0	0.5216	$0	$0
10	$0	$0	$0	0.4852	$0	$0
	$1,111,000	**$706,483**	**$94,486**			**$1,754,163**

Plume H - Perimeter, Exsitu ***$1,800,000***

PRESENT WORTH CALCULATIONS

Plume H - Perimeter, Exsitu - without 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$242,962	$0	$0	1.0000	$242,962	$242,962
1	$0	$9,802	$13,498	0.9302	$23,300	$21,675
2	$0	$9,802	$13,498	0.8653	$23,300	$20,163
3	$0	$9,802	$13,498	0.8050	$23,300	$18,756
4	$0	$9,802	$13,498	0.7488	$23,300	$17,447
5	$0	$9,802	$13,498	0.6966	$23,300	$16,230
6	$0	$0	$13,498	0.6480	$13,498	$8,746
7	$0	$0	$13,498	0.6028	$13,498	$8,136
8	$0	$0	$0	0.5607	$0	$0
9	$0	$0	$0	0.5216	$0	$0
10	$0	$0	$0	0.4852	$0	$0
	$242,962	**$49,012**	**$94,486**			**$354,115**

Plume H - Perimeter, Exsitu ***$400,000***

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$3,048**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 10 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$3,840**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$1,250**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 10 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$13,498**

PRESENT WORTH CALCULATIONS

ANNUAL DISCOUNT RATE = 7.5%

YEAR	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$0	1.0000	$0	$0
1	$13,498	0.9302	$13,498	$12,556
2	$13,498	0.8653	$13,498	$11,680
3	$13,498	0.8050	$13,498	$10,865
4	$13,498	0.7488	$13,498	$10,107
5	$13,498	0.6966	$13,498	$9,402
6	$13,498	0.6480	$13,498	$8,746
7	$13,498	0.6028	$13,498	$8,136
8	$13,498	0.5607	$13,498	$7,568
9	$13,498	0.5216	$13,498	$7,040
10	$13,498	0.4852	$13,498	$6,549
11	$13,498	0.4513	$13,498	$6,092
12	$13,498	0.4199	$13,498	$5,667
13	$13,498	0.3906	$13,498	$5,272
14	$13,498	0.3633	$13,498	$4,904
15	$13,498	0.3380	$13,498	$4,562
16	$13,498	0.3144	$13,498	$4,244
17	$13,498	0.2925	$13,498	$3,948
18	$13,498	0.2720	$13,498	$3,672
19	$13,498	0.2531	$13,498	$3,416
20	$13,498	0.2354	$13,498	$3,178
21	$13,498	0.2190	$13,498	$2,956
22	$13,498	0.2037	$13,498	$2,750
23	$13,498	0.1895	$13,498	$2,558
24	$13,498	0.1763	$13,498	$2,379
25	$13,498	0.1640	$13,498	$2,213
26	$13,498	0.1525	$13,498	$2,059
27	$13,498	0.1419	$13,498	$1,915
28	$13,498	0.1320	$13,498	$1,782
29	$13,498	0.1228	$13,498	$1,657
30	$13,498	0.1142	$13,498	$1,542
	$404,940			**$159,417**

Plume I - Source Area, Natural Attenuation ***$160,000***

CAPITAL COSTS

1. Collector Trench Installation **$176,910**

Assume Trench costs at $225 /linear foot
Assume 750 linear feet of trench
750 lf at $225 /lf = $168,750
Includes trench and sumps installed at 300 ft intervals

Pump Installation
Assume 4 pump stations
Cost of Pump and Motor = $1,700
Installation (assumed at 20% of capital) $340
Subtotal $2,040

4 pumps at $2,040 each = $8,160

2. Bioremediation Injection Well Installation **$73,070**

A. Drilling $60,000

Assume Drilling costs at $150 per linear foot
Assume 10 wells at an average depth of 40 ft
Total 10 wells 400 linear feet

B. Fencing (assume each well enclosed by 20 ft by 20 ft fence with one 12 ft gate) $13,070

68 linear feet of fence per well at $10.28 /lf = $699
1 12 ft gates per well at $608 ea = $608
Subtotal = $1,307

10 wells at $1,307 /well = $13,070

4. Pipe Installation (from extraction & injection point to header) **$52,927**

A. HDPE Pipe $32,527

Pipe I.D., Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Unit Cost Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
Ext 2"	3,150	158	$4.64	$1.37	$19,895
Rtn 2"	2,000	100	$4.64	$1.37	$12,632
			Subtotal		$32,527

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

B. Electrical and Instrumentation $20,400

Assume $3,000 per well to install cable, conduit, and handholes
4 stations $3,000 per station $12,000
Assume $600 per well to install valves and flow elements
14 stations $600 per station $8,400

5. Treatment System (Bioremediation) **$99,069**

A. Treatment/Storage/Office Building **$18,180**

Plume I - Source Area, In-Situ

Assume a 20 ft x 20 ft building to house the each bioremediation treatment system

Concrete Foundation	15 CY (20ft x 20ft x 1 ft thick)			
Excavation	15 CY at	$3.25	/CY =	$49
Compaction	15 CY at	$2.43	/CY =	$36
Placement	15 CY at	$139.68	/CY =	$2,095
Pre-Engineered Structure	400 square ft			
Including Building, Insulation, HVAC unit, Electrical, and Lighting.				
Assume	$40.00 /square ft =	$16,000		

B. Power to site **$28,446**

	Materials	Installation	Subtotal
Oil Filled Pad Mounted 112.5 KVA Transformer	$14,069	$426	$14,495
Watthour-meter and current transformers	$1,500	$500	$2,000
600A Main Circuit, breaker distribution	$10,451	$1,500	$11,951

C. In Situ Bioremediation Equipment **$46,785**

2,000 gallon H20 holding tank			$1,570
27.5 gpm pump			$1,295
1,000 gallon Methanol holding tank			$996
Metering pump			$1,627
Skid, tank penetrations, and delivery			$3,500
Braided Hose			$187
Cost of PLC			$5,942
Installation of PLC			$1,188.40
Programming of PLC			
(assume one engineer and one technician for 6 weeks per system)			
$54 /hr for	6 weeks =		$12,960
$48 /hr for	6 weeks =		$11,520
Flow measuring and control devices			$6,000
Assume $5,000 for all valves and flow devices			
Labor $1,000 (assumed at 20% of capital)			

D. Fencing **$5,657**

Assume each In-Situ Bioremediation system enclosed by 60 bt by 60 ft fence with two 12 ft gate

432 linear feet of fence at	$10.28 /lf =	$4,441	
2 12 ft gates at	$608 ea =	$1,216	

6. Treatment System (52 gpm UV/OX) **$216,190**

Based on a ratio of flow rates relative to the cost of a 400 GPM system **$216,190**

System flow =	52 gpm	
Cost of	400 gpm system =	$1,663,000
Cost of the	52 gpm system =	$216,190

7. Testing **$12,240**

Assume 4 technicians and 2 engineers for 3 weeks to test the system

4 Technicians at	$48 /hr for	3 weeks =	$5,760	
2 Engineers at	$54 /hr for	3 weeks =	$6,480	

8. Implementation Costs **$153,260**

Plume I - Source Area, In-Situ

Assume Implementation costs at 37% of Capital Costs
Includes Permitting and legal, Services During Construction, Health and Safety,
Report preparation, and engineering design costs.

TOTAL CAPITAL COSTS

Without Treatment System		With Treatment System	
Subtotal (ST)	**$567,477**	Subtotal (ST)	**$784,000**
Overhead and Profit @ 15.5%	**$88,000**	Overhead and Profit @ 15.5%	**$122,000**
Mob/Bond/Insur @ 5% of ST	**$28,000**	Mob/Bond/Insur @ 5% of ST	**$39,000**
Contingency @ 10% of ST	**$57,000**	Contingency @ 10% of ST	**$78,000**
Total	**$740,477**	Total	**$1,023,000**

O & M COSTS

1. Electrical Costs **$4,901**

Extraction System:

Assume	9	HP pump (Bioremediation system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation **$95,776**

A. Labor and Maintenance **$40,314**

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	52	gpm	
Cost of	400	gpm system =	$310,111
Cost of the	52	gpm system =	$40,314

B. Treatment System Influent and Effluent Water Monitoring **$2,421**

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	52	gpm	
Cost of	400	gpm system =	$18,624
Cost of the	52	gpm system =	$2,421

C. Insitu Bio System Operation **$53,040**

Assume 1 technician and 1 engineer quarter time to operate the system

1 Technician at	$48	/hr for	13 weeks =	$24,960
1 Engineer at	$54	/hr for	13 weeks =	$28,080

3. Extraction Well Pump Replacement **$6,204**

Assume extraction pumps will require replacement every 5 years

Assume Installation technicians @ $48 /hour/technician
Assume 16 hours per well for pump installation

4 pumps at	$788	each =	$3,152
16 hrs/well at	$48	/hr =	$763 per well
4 wells at	$763	/well =	$3,052 installation

Total O&M With Treatment System	**$100,677**
O & M with 5 year Replacement	**$106,881**

Total O&M Without Treatment System	**$57,941**
O & M with 5 year Replacement	**$64,145**

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$3,048**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 10 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110 /sample
Total (including 15% CLP) =	$127 /sample event

2. Labor (for Groundwater Well Sampling) **$3,840**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$1,250**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 10 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$13,498**

PRESENT WORTH CALCULATIONS

Plume D - Source Area, In-Situ Treatment - with 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$1,023,000	$0	$0	1.0000	$1,023,000	$1,023,000
1	$0	$100,677	$13,498	0.9302	$114,175	$106,209
2	$0	$100,677	$13,498	0.8653	$114,175	$98,799
3	$0	$100,677	$13,498	0.8050	$114,175	$91,906
4	$0	$100,677	$13,498	0.7488	$114,175	$85,494
5	$0	$106,881	$13,498	0.6966	$120,379	$83,851
6	$0	$100,677	$13,498	0.6480	$114,175	$73,981
7	$0	$100,677	$13,498	0.6028	$114,175	$68,819
8	$0	$100,677	$13,498	0.5607	$114,175	$64,018
9	$0	$100,677	$13,498	0.5216	$114,175	$59,552
10	$0	$106,881	$13,498	0.4852	$120,379	$58,407
11	$0	$100,677	$13,498	0.4513	$114,175	$51,532
12	$0	$100,677	$13,498	0.4199	$114,175	$47,937
13	$0	$100,677	$13,498	0.3906	$114,175	$44,592
14	$0	$100,677	$13,498	0.3633	$114,175	$41,481
15	$0	$106,881	$13,498	0.3380	$120,379	$40,684
16	$0	$100,677	$13,498	0.3144	$114,175	$35,895
17	$0	$100,677	$13,498	0.2925	$114,175	$33,391
18	$0	$100,677	$13,498	0.2720	$114,175	$31,061
19	$0	$100,677	$13,498	0.2531	$114,175	$28,894
20	$0	$106,881	$13,498	0.2354	$120,379	$28,339
21	$0	$100,677	$13,498	0.2190	$114,175	$25,003
22	$0	$100,677	$13,498	0.2037	$114,175	$23,259
23	$0	$0	$13,498	0.1895	$13,498	$2,558
24	$0	$0	$13,498	0.1763	$13,498	$2,379
25	$0	$0	$13,498	0.1640	$13,498	$2,213
26	$0	$0	$13,498	0.1525	$13,498	$2,059
27	$0	$0	$13,498	0.1419	$13,498	$1,915
28	$0	$0	$13,498	0.1320	$13,498	$1,782
29	$0	$0	$13,498	0.1228	$13,498	$1,657
30	$0	$0	$13,498	0.1142	$13,498	$1,542
	$1,023,000	$2,239,796	$404,940			$2,262,210

Plume D - Source Area, In-Situ Treatment ***$2,300,000***

PRESENT WORTH CALCULATIONS

Plume I - Source Area, In-Situ Treatment - without 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$740,477	$0	$0	1.0000	$740,477	$740,477
1	$0	$57,941	$13,498	0.9302	$71,439	$66,455
2	$0	$57,941	$13,498	0.8653	$71,439	$61,819
3	$0	$57,941	$13,498	0.8050	$71,439	$57,506
4	$0	$57,941	$13,498	0.7488	$71,439	$53,494
5	$0	$64,145	$13,498	0.6966	$77,643	$54,083
6	$0	$57,941	$13,498	0.6480	$71,439	$46,290
7	$0	$57,941	$13,498	0.6028	$71,439	$43,060
8	$0	$57,941	$13,498	0.5607	$71,439	$40,056
9	$0	$57,941	$13,498	0.5216	$71,439	$37,262
10	$0	$64,145	$13,498	0.4852	$77,643	$37,672
11	$0	$57,941	$13,498	0.4513	$71,439	$32,244
12	$0	$57,941	$13,498	0.4199	$71,439	$29,994
13	$0	$57,941	$13,498	0.3906	$71,439	$27,901
14	$0	$57,941	$13,498	0.3633	$71,439	$25,955
15	$0	$64,145	$13,498	0.3380	$77,643	$26,241
16	$0	$57,941	$13,498	0.3144	$71,439	$22,460
17	$0	$57,941	$13,498	0.2925	$71,439	$20,893
18	$0	$57,941	$13,498	0.2720	$71,439	$19,435
19	$0	$57,941	$13,498	0.2531	$71,439	$18,079
20	$0	$64,145	$13,498	0.2354	$77,643	$18,278
21	$0	$57,941	$13,498	0.2190	$71,439	$15,644
22	$0	$57,941	$13,498	0.2037	$71,439	$14,553
23	$0	$0	$13,498	0.1895	$13,498	$2,558
24	$0	$0	$13,498	0.1763	$13,498	$2,379
25	$0	$0	$13,498	0.1640	$13,498	$2,213
26	$0	$0	$13,498	0.1525	$13,498	$2,059
27	$0	$0	$13,498	0.1419	$13,498	$1,915
28	$0	$0	$13,498	0.1320	$13,498	$1,782
29	$0	$0	$13,498	0.1228	$13,498	$1,657
30	$0	$0	$13,498	0.1142	$13,498	$1,542
	$740,477	**$1,299,523**	**$404,940**			**$1,625,955**

Plume I - Source Area, In-Situ Treatment ***$1,500,000***

Plume I - Source Area, Exsitu

CAPITAL COSTS

1. Collector Trench Installation **$176,910**

Assume Trench costs at $225 /linear foot
Assume 750 linear feet of trench
750 lf at $225 /lf = $168,750
Includes trench and sumps installed at 300 ft intervals

Pump Installation
Assume 4 pump stations
Cost of Pump and Motor = $1,700
Installation (assumed at 20% of capital) $340
Subtotal $2,040

4 pumps at $2,040 each = $8,160

2. Extraction Pipe Installation (from extraction point to header) **$28,611**

A. HDPE Pipe $14,211

Pipe I.D., Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
2	2,250	113	$4.64	$1.37	$14,211
				Subtotal	$14,211

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

B. Electrical and Instrumentation $14,400

Assume $3,000 per pump station to install cable, conduit, and handholes
4 stations at $3,000 per station $12,000

Assume $600 per pump station to install valves and flow elements
4 stations at $600 per station $2,400

3. Treatment System (40 gpm UV/OX) **$166,300**

A. Treatment System $166,300

Based on a ratio of flow rates relative to the cost of a 400 GPM system
System flow = 40 gpm
Cost of 400 gpm system = $1,663,000
Cost of the 40 gpm system = $166,300

TOTAL CAPITAL COSTS

Without Treatment System		With Treatment System	
Subtotal (ST)	**$205,521**	Subtotal (ST)	**$372,000**
Overhead and Profit @ 15.5%	**$32,000**	Overhead and Profit @ 15.5%	**$58,000**
Mob/Bond/Insur @ 5% of ST	**$10,000**	Mob/Bond/Insur @ 5% of ST	**$19,000**
Contingency @ 10% of ST	**$21,000**	Contingency @ 10% of ST	**$37,000**
Total	**$268,521**	Total	**$486,000**

O & M COSTS

1. Electrical Costs **$4,901**

Extraction System:

Assume	9	HP pump (35 GPM system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation **$32,874**

A. Labor and Maintenance $31,011

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	40	gpm	
Cost of	400	gpm system =	$310,111
Cost of the	40	gpm system =	$31,011

B. Treatment System Influent and Effluent Water Monitoring $1,862

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	40	gpm	
Cost of	400	gpm system =	$18,624
Cost of the	40	gpm system =	$1,862

3. Extraction Trench Pump Replacement **$3,915**

Assume extraction pumps will require replacement every 5 years

Assume Installation technicians @ $48 /hour/technician

Assume 16 hours per well for pump installation

4 pumps at	$788	each =	$3,152
16 hrs/pump at	$48	/hr =	$763 per pump

Total O&M With Treatment system	**$37,775**
O & M with 5 year Replacement	**$41,690**
Total O&M Without Treatment system	**$4,901**
O & M with 5 year Replacement	**$8,816**

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$3,048**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 10 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling)	**$3,840**
Assume rate for 2 sampling technicians @ $48 /hour/technician Assume 2 hours/well/sampling event for sampling, shipping, etc. Assume 2 sample events/year	
3. Rental of Equipment (for Groundwater Well Sampling)	**$1,250**
Assume rental of sampling equipment, shipping, etc. @ $250/day Assume 10 existing groundwater monitoring wells Assume 2 hours per well for sampling Assume 2 sample events/year	
4. Labor (for Data Analysis and Validation of Groundwater Data)	**$5,360**
Assume 1 man-week per sampling event Assume chargeout rate for 1 - Validation Chemist @ $67/hour Assume 2 sample events/year	
TOTAL MONITORING COSTS	**$13,498**

PRESENT WORTH CALCULATIONS

Plume I - Source Area, Exsitu - with 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$486,000	$0	$0	1.0000	$486,000	$486,000
1	$0	$37,775	$13,498	0.9302	$51,273	$47,696
2	$0	$37,775	$13,498	0.8653	$51,273	$44,368
3	$0	$37,775	$13,498	0.8050	$51,273	$41,273
4	$0	$37,775	$13,498	0.7488	$51,273	$38,393
5	$0	$41,690	$13,498	0.6966	$55,188	$38,442
6	$0	$37,775	$13,498	0.6480	$51,273	$33,223
7	$0	$37,775	$13,498	0.6028	$51,273	$30,905
8	$0	$37,775	$13,498	0.5607	$51,273	$28,749
9	$0	$37,775	$13,498	0.5216	$51,273	$26,743
10	$0	$41,690	$13,498	0.4852	$55,188	$26,777
11	$0	$37,775	$13,498	0.4513	$51,273	$23,142
12	$0	$37,775	$13,498	0.4199	$51,273	$21,527
13	$0	$37,775	$13,498	0.3906	$51,273	$20,025
14	$0	$37,775	$13,498	0.3633	$51,273	$18,628
15	$0	$41,690	$13,498	0.3380	$55,188	$18,652
16	$0	$37,775	$13,498	0.3144	$51,273	$16,119
17	$0	$37,775	$13,498	0.2925	$51,273	$14,995
18	$0	$37,775	$13,498	0.2720	$51,273	$13,949
19	$0	$37,775	$13,498	0.2531	$51,273	$12,976
20	$0	$41,690	$13,498	0.2354	$55,188	$12,992
21	$0	$37,775	$13,498	0.2190	$51,273	$11,228
22	$0	$37,775	$13,498	0.2037	$51,273	$10,445
23	$0	$0	$13,498	0.1895	$13,498	$2,558
24	$0	$0	$13,498	0.1763	$13,498	$2,379
25	$0	$0	$13,498	0.1640	$13,498	$2,213
26	$0	$0	$13,498	0.1525	$13,498	$2,059
27	$0	$0	$13,498	0.1419	$13,498	$1,915
28	$0	$0	$13,498	0.1320	$13,498	$1,782
29	$0	$0	$13,498	0.1228	$13,498	$1,657
30	$0	$0	$13,498	0.1142	$13,498	$1,542
	$486,000	**$846,705**	**$404,940**			**$1,053,350**

Plume I - Source Area, Exsitu ***$1,100,000***

PRESENT WORTH CALCULATIONS

Plume I - Source Area, Exsitu - without 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$268,521	$0	$0	1.0000	$268,521	$268,521
1	$0	$4,901	$13,498	0.9302	$18,399	$17,116
2	$0	$4,901	$13,498	0.8653	$18,399	$15,921
3	$0	$4,901	$13,498	0.8050	$18,399	$14,811
4	$0	$4,901	$13,498	0.7488	$18,399	$13,777
5	$0	$8,816	$13,498	0.6966	$22,314	$15,543
6	$0	$4,901	$13,498	0.6480	$18,399	$11,922
7	$0	$4,901	$13,498	0.6028	$18,399	$11,090
8	$0	$4,901	$13,498	0.5607	$18,399	$10,316
9	$0	$4,901	$13,498	0.5216	$18,399	$9,597
10	$0	$8,816	$13,498	0.4852	$22,314	$10,827
11	$0	$4,901	$13,498	0.4513	$18,399	$8,304
12	$0	$4,901	$13,498	0.4199	$18,399	$7,725
13	$0	$4,901	$13,498	0.3906	$18,399	$7,186
14	$0	$4,901	$13,498	0.3633	$18,399	$6,685
15	$0	$8,816	$13,498	0.3380	$22,314	$7,541
16	$0	$4,901	$13,498	0.3144	$18,399	$5,784
17	$0	$4,901	$13,498	0.2925	$18,399	$5,381
18	$0	$4,901	$13,498	0.2720	$18,399	$5,005
19	$0	$4,901	$13,498	0.2531	$18,399	$4,656
20	$0	$8,816	$13,498	0.2354	$22,314	$5,253
21	$0	$4,901	$13,498	0.2190	$18,399	$4,029
22	$0	$4,901	$13,498	0.2037	$18,399	$3,748
23	$0	$0	$13,498	0.1895	$13,498	$2,558
24	$0	$0	$13,498	0.1763	$13,498	$2,379
25	$0	$0	$13,498	0.1640	$13,498	$2,213
26	$0	$0	$13,498	0.1525	$13,498	$2,059
27	$0	$0	$13,498	0.1419	$13,498	$1,915
28	$0	$0	$13,498	0.1320	$13,498	$1,782
29	$0	$0	$13,498	0.1228	$13,498	$1,657
30	$0	$0	$13,498	0.1142	$13,498	$1,542
	$268,521	**$123,487**	**$404,940**			**$486,846**

Plume I - Source Area, Exsitu ***$500,000***

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$3,048**

Assume one sample semiannually until system shutdown
Assume 12 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 10 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$3,840**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$1,250**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 10 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$13,498**

PRESENT WORTH CALCULATIONS

ANNUAL DISCOUNT RATE = 7.5%

YEAR	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$0	1.0000	$0	$0
1	$13,498	0.9302	$13,498	$12,556
2	$13,498	0.8653	$13,498	$11,680
3	$13,498	0.8050	$13,498	$10,865
4	$13,498	0.7488	$13,498	$10,107
5	$13,498	0.6966	$13,498	$9,402
6	$13,498	0.6480	$13,498	$8,746
7	$13,498	0.6028	$13,498	$8,136
8	$13,498	0.5607	$13,498	$7,568
9	$13,498	0.5216	$13,498	$7,040
10	$13,498	0.4852	$13,498	$6,549
11	$13,498	0.4513	$13,498	$6,092
12	$13,498	0.4199	$13,498	$5,667
13	$13,498	0.3906	$13,498	$5,272
14	$13,498	0.3633	$13,498	$4,904
15	$13,498	0.3380	$13,498	$4,562
16	$13,498	0.3144	$13,498	$4,244
17	$13,498	0.2925	$13,498	$3,948
18	$13,498	0.2720	$13,498	$3,672
19	$13,498	0.2531	$13,498	$3,416
20	$13,498	0.2354	$13,498	$3,178
21	$13,498	0.2190	$13,498	$2,956
22	$13,498	0.2037	$13,498	$2,750
23	$13,498	0.1895	$13,498	$2,558
24	$13,498	0.1763	$13,498	$2,379
25	$13,498	0.1640	$13,498	$2,213
26	$13,498	0.1525	$13,498	$2,059
27	$13,498	0.1419	$13,498	$1,915
28	$13,498	0.1320	$13,498	$1,782
29	$13,498	0.1228	$13,498	$1,657
30	$13,498	0.1142	$13,498	$1,542
	$404,940			**$159,417**

Plume I - Perimeter, Natural Attenuation ***$160,000***

Plume I - Perimeter, Exsitu

CAPITAL COSTS

1. Collector Trench Installation **$210,660**

Assume Trench costs at $225 /linear foot
Assume 900 linear feet of trench
900 lf at $225 /lf = $202,500
Includes trench and sumps installed at 300 ft intervals

Pump Installation
Assume 4 pump stations
Cost of Pump and Motor = $1,700
Installation (assumed at 20% of capital) $340
Subtotal $2,040

4 pumps at $2,040 each = $8,160

2. Extraction Pipe Installation (from extraction point to header) **$32,716**

A. HDPE Pipe $18,316

Pipe I.D., Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
2	2,900	145	$4.64	$1.37	$18,316
			Subtotal		$18,316

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

B. Electrical and Instrumentation $14,400

Assume $3,000 per pump station to install cable, conduit, and handholes
4 stations at $3,000 per station $12,000

Assume $600 per pump station to install valves and flow elements
4 stations at $600 per station $2,400

3. Treatment System **$0**

A. Treatment System will be an existing system with excess capacity, assume no capital cost. $0

TOTAL CAPITAL COSTS

Subtotal (ST)*	**$81,000**
Overhead and Profit @ 15.5%	**$13,000**
Mob/Bond/Insur @ 5% of ST	**$4,000**
Contingency @ 10% of ST	**$8,000**
Total	**$106,000**

*** Subtotal is 1/3 of cost to reflect costs being shared by plumes F and I.**

O & M COSTS

1. Electrical Costs **$4,901**

Plume I - Perimeter, Exsitu

Extraction System:

Assume	9	HP pump (35 GPM system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation **$57,529**

A. Labor and Maintenance $54,269

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	70	gpm	
Cost of	400	gpm system =	$310,111
Cost of the	70	gpm system =	$54,269

B. Treatment System Influent and Effluent Water Monitoring $3,259

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	70	gpm	
Cost of	400	gpm system =	$18,624
Cost of the	70	gpm system =	$3,259

3. Extraction Trench Pump Replacement **$3,915**

Assume extraction pumps will require replacement every 5 years

Assume Installation technicians @ $48 /hour/technician

Assume 16 hours per well for pump installation

4 pumps at	$788	each =	$3,152	
16 hrs/pump at	$48	/hr =	$763	per pump

	Total O&M With Treatment System*	**$20,810**
*O&M Costs divided by 3 to reflect sharing with Plumes F & I	O & M with 5 year Replacement	**$22,115**
	Total O&M Without Treatment System*	**$1,634**
	O & M with 5 year Replacement	**$2,939**

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$3,048**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 10 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$3,840**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling)	**$1,250**
Assume rental of sampling equipment, shipping, etc. @ $250/day Assume 10 existing groundwater monitoring wells Assume 2 hours per well for sampling Assume 2 sample events/year	
4. Labor (for Data Analysis and Validation of Groundwater Data)	**$5,360**
Assume 1 man-week per sampling event Assume chargeout rate for 1 - Validation Chemist @ $67/hour Assume 2 sample events/year	
TOTAL MONITORING COSTS	**$13,498**

PRESENT WORTH CALCULATIONS

Plume 1 - Perimeter, Exsitu - with 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$106,000	$0	$0	1.0000	$106,000	$106,000
1	$0	$20,810	$13,498	0.9302	$34,308	$31,914
2	$0	$20,810	$13,498	0.8653	$34,308	$29,688
3	$0	$20,810	$13,498	0.8050	$34,308	$27,617
4	$0	$20,810	$13,498	0.7488	$34,308	$25,690
5	$0	$22,115	$13,498	0.6966	$35,613	$24,807
6	$0	$20,810	$13,498	0.6480	$34,308	$22,230
7	$0	$20,810	$13,498	0.6028	$34,308	$20,679
8	$0	$20,810	$13,498	0.5607	$34,308	$19,237
9	$0	$20,810	$13,498	0.5216	$34,308	$17,894
10	$0	$22,115	$13,498	0.4852	$35,613	$17,279
11	$0	$20,810	$13,498	0.4513	$34,308	$15,485
12	$0	$20,810	$13,498	0.4199	$34,308	$14,404
13	$0	$20,810	$13,498	0.3906	$34,308	$13,399
14	$0	$20,810	$13,498	0.3633	$34,308	$12,465
15	$0	$22,115	$13,498	0.3380	$35,613	$12,036
16	$0	$20,810	$13,498	0.3144	$34,308	$10,786
17	$0	$20,810	$13,498	0.2925	$34,308	$10,033
18	$0	$20,810	$13,498	0.2720	$34,308	$9,333
19	$0	$20,810	$13,498	0.2531	$34,308	$8,682
20	$0	$22,115	$13,498	0.2354	$35,613	$8,384
21	$0	$20,810	$13,498	0.2190	$34,308	$7,513
22	$0	$20,810	$13,498	0.2037	$34,308	$6,989
23	$0	$20,810	$13,498	0.1895	$34,308	$6,501
24	$0	$20,810	$13,498	0.1763	$34,308	$6,048
25	$0	$22,115	$13,498	0.1640	$35,613	$5,840
26	$0	$20,810	$13,498	0.1525	$34,308	$5,233
27	$0	$20,810	$13,498	0.1419	$34,308	$4,868
28	$0	$20,810	$13,498	0.1320	$34,308	$4,529
29	$0	$20,810	$13,498	0.1228	$34,308	$4,213
30	$0	$20,810	$13,498	0.1142	$34,308	$3,919
	$106,000	**$630,824**	**$404,940**			**$513,695**

Plume 1 - Perimeter, Exsitu

$500,000

PRESENT WORTH CALCULATIONS

Plume 1 - Perimeter, Exsitu - withoout 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$106,000	$0	$0	1.0000	$106,000	$106,000
1	$0	$1,634	$13,498	0.9302	$15,132	$14,076
2	$0	$1,634	$13,498	0.8653	$15,132	$13,094
3	$0	$1,634	$13,498	0.8050	$15,132	$12,180
4	$0	$1,634	$13,498	0.7488	$15,132	$11,331
5	$0	$2,939	$13,498	0.6966	$16,437	$11,449
6	$0	$1,634	$13,498	0.6480	$15,132	$9,805
7	$0	$1,634	$13,498	0.6028	$15,132	$9,121
8	$0	$1,634	$13,498	0.5607	$15,132	$8,484
9	$0	$1,634	$13,498	0.5216	$15,132	$7,892
10	$0	$2,939	$13,498	0.4852	$16,437	$7,975
11	$0	$1,634	$13,498	0.4513	$15,132	$6,830
12	$0	$1,634	$13,498	0.4199	$15,132	$6,353
13	$0	$1,634	$13,498	0.3906	$15,132	$5,910
14	$0	$1,634	$13,498	0.3633	$15,132	$5,498
15	$0	$2,939	$13,498	0.3380	$16,437	$5,555
16	$0	$1,634	$13,498	0.3144	$15,132	$4,757
17	$0	$1,634	$13,498	0.2925	$15,132	$4,425
18	$0	$1,634	$13,498	0.2720	$15,132	$4,117
19	$0	$1,634	$13,498	0.2531	$15,132	$3,829
20	$0	$2,939	$13,498	0.2354	$16,437	$3,869
21	$0	$1,634	$13,498	0.2190	$15,132	$3,314
22	$0	$1,634	$13,498	0.2037	$15,132	$3,082
23	$0	$1,634	$13,498	0.1895	$15,132	$2,867
24	$0	$1,634	$13,498	0.1763	$15,132	$2,667
25	$0	$2,939	$13,498	0.1640	$16,437	$2,695
26	$0	$1,634	$13,498	0.1525	$15,132	$2,308
27	$0	$1,634	$13,498	0.1419	$15,132	$2,147
28	$0	$1,634	$13,498	0.1320	$15,132	$1,997
29	$0	$1,634	$13,498	0.1228	$15,132	$1,858
30	$0	$1,634	$13,498	0.1142	$15,132	$1,728
	$106,000	**$55,637**	**$404,940**			**$287,216**

Plume 1 - Perimeter, Exsitu ***$300,000***

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis	**$1,524**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 5 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling)	**$1,920**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling)	**$625**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 5 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data)	**$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS	**$9,429**

PRESENT WORTH CALCULATIONS

ANNUAL DISCOUNT RATE = 7.5%

YEAR	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$0	1.0000	$0	$0
1	$9,429	0.9302	$9,429	$8,771
2	$9,429	0.8653	$9,429	$8,159
3	$9,429	0.8050	$9,429	$7,590
4	$9,429	0.7488	$9,429	$7,060
5	$9,429	0.6966	$9,429	$6,568
6	$9,429	0.6480	$9,429	$6,110
7	$9,429	0.6028	$9,429	$5,683
8	$0	0.5607	$0	$0
9	$0	0.5216	$0	$0
10	$0	0.4852	$0	$0
11	$0	0.4513	$0	$0
12	$0	0.4199	$0	$0
13	$0	0.3906	$0	$0
14	$0	0.3633	$0	$0
15	$0	0.3380	$0	$0
16	$0	0.3144	$0	$0
17	$0	0.2925	$0	$0
18	$0	0.2720	$0	$0
19	$0	0.2531	$0	$0
20	$0	0.2354	$0	$0
21	$0	0.2190	$0	$0
22	$0	0.2037	$0	$0
23	$0	0.1895	$0	$0
24	$0	0.1763	$0	$0
25	$0	0.1640	$0	$0
26	$0	0.1525	$0	$0
27	$0	0.1419	$0	$0
28	$0	0.1320	$0	$0
29	$0	0.1228	$0	$0
30	$0	0.1142	$0	$0
	$66,003			**$49,942**

Plume J - Perimeter, Natural Attenuation ***$50,000***

CAPITAL COSTS

1. Bioremediation Extraction Well Installation **$230,309**

A. Drilling $156,000

Assume Drilling costs at			$150	per linear foot	
Assume	26	wells at an average depth of		40	ft
Total	26	wells		1,040	linear feet

B. Pump Installation $40,326

Assume Installation technicians @			$48	/hour/technician	
Assume	16	hours per well for pump installation			
26	pumps at	$788	each =	$20,488	
16	hrs/well at	$48	/hr =	$763	per well
26	wells at	$763	/well =	$19,838	installation

C. Fencing (assume each well enclosed by 20 ft by 20 ft fence with one 12 ft gate) $33,983

68	linear feet of fence per well at	$10.28	/lf =	$699
1	12 ft gates per well at	$608	ea =	$608
			Subtotal =	$1,307

26	wells at	$1,307	/well =	$33,983

2. Bioremediation Injection Well Installation **$146,141**

A. Drilling $120,000

Assume Drilling costs at			$150	per linear foot	
Assume	20	wells at an average depth of		40	ft
Total	20	wells		800	linear feet

B. Fencing (assume each well enclosed by 20 ft by 20 ft fence with one 12 ft gate) $26,141

68	linear feet of fence per well at	$10.28	/lf =	$699
1	12 ft gates per well at	$608	ea =	$608
			Subtotal =	$1,307

20	wells at	$1,307	/well =	$26,141

4. Pipe Installation (from extraction & injection point to header) **$155,365**

A. HDPE Pipe $49,765

Pipe I.D., Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Unit Cost Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
Ext 2"	1,920	96	$4.64	$1.37	$12,127
Ext 4"	1,980	99	$0.00	$2.61	$5,427
Rtn 2"	5,100	255	$4.64	$1.37	$32,212
			Subtotal		$49,765

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

B. Electrical and Instrumentation — $105,600

Assume $3,000 per well to install cable, conduit, and handholes
26 wells at $3,000 per well = $78,000
Assume $600 per well to install valves and flow elements
46 wells at $600 per well = $27,600

5. Treatment System (Bioremediation) — **$99,069**

A. Treatment/Storage/Office Building — $18,180

Assume a 20 ft x 20 ft building to house the each bioremediation treatment system

Concrete Foundation	15 CY (20ft x 20ft x 1 ft thick)			
Excavation	15 CY at	$3.25	/CY =	$49
Compaction	15 CY at	$2.43	/CY =	$36
Placement	15 CY at	$139.68	/CY =	$2,095
Pre-Engineered Structure	400 square ft			

Including Building, Insulation, HVAC unit, Electrical, and Lighting.
Assume $40.00 /square ft = $16,000

B. Power to site — $28,446

	Materials	Installation	Subtotal
Oil Filled Pad Mounted 112.5 KVA Transformer	$14,069	$426	$14,495
Watthour-meter and current transformers	$1,500	$500	$2,000
600A Main Circuit, breaker distribution	$10,451	$1,500	$11,951

C. In Situ Bioremediation Equipment — $46,785

2,000 gallon H20 holding tank		$1,570
27.5 gpm pump		$1,295
1,000 gallon Methanol holding tank		$996
Metering pump		$1,627
Skid, tank penetrations, and delivery		$3,500
Braided Hose		$187
Cost of PLC		$5,942
Installation of PLC		$1,188.40
Programming of PLC		
(assume one engineer and one technician for 6 weeks per system)		
$54 /hr for	6 weeks =	$12,960
$48 /hr for	6 weeks =	$11,520
Flow measuring and control devices		$6,000
Assume $5,000 for all valves and flow devices		
Labor $1,000 (assumed at 20% of capital)		

D. Fencing — $5,657

Assume each In-Situ Bioremediation system enclosed by 60 bt by 60 ft fence with two 12 ft gate

432 linear feet of fence at	$10.28 /lf =	$4,441
2 12 ft gates at	$608 ea =	$1,216

6. Treatment System (100 gpm UV/OX) — **$415,750**

Based on a ratio of flow rates relative to the cost of a 400 GPM system — $415,750

System flow =	100 gpm	
Cost of	400 gpm system =	$1,663,000

Plume J - Perimeter, In-Situ

Cost of the	100 gpm system =	$415,750	

. Testing **$12,240**

Assume 4 technicians and 2 engineers for 3 weeks to test the system

4 Technicians at	$48 /hr for	3 weeks =	$5,760	
2 Engineers at	$54 /hr for	3 weeks =	$6,480	

8. Implementation Costs **$237,956**

Assume Implementation costs at 37% of Capital Costs
Includes Permitting and legal, Services During Construction, Health and Safety, Report preparation, and engineering design costs.

TOTAL CAPITAL COSTS

Without Treatment System		With Treatment System	
Subtotal (ST)	**$881,079**	Subtotal (ST)	**$1,297,000**
Overhead and Profit @ 15.5%	**$137,000**	Overhead and Profit @ 15.5%	**$201,000**
Mob/Bond/Insur @ 5% of ST	**$44,000**	Mob/Bond/Insur @ 5% of ST	**$65,000**
Contingency @ 10% of ST	**$88,000**	Contingency @ 10% of ST	**$130,000**
Total	**$1,150,079**	Total	**$1,693,000**

O & M COSTS

1. Electrical Costs **$11,164**

Extraction System:

Assume	20.5	HP pump (Bioremediation system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation **$135,224**

A. Labor and Maintenance **$77,528**

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	100 gpm	
Cost of	400 gpm system =	$310,111
Cost of the	100 gpm system =	$77,528

B. Treatment System Influent and Effluent Water Monitoring $4,656

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	100 gpm	
Cost of	400 gpm system =	$18,624
Cost of the	100 gpm system =	$4,656

C. Insitu Bio System Operation $53,040

Assume 1 technician and 1 engineer quarter time to operate the system

1 Technician at	$48 /hr for	13 weeks =	$24,960
1 Engineer at	$54 /hr for	13 weeks =	$28,080

3. Extraction Well Pump Replacement **$40,326**

Assume extraction pumps will require replacement every 5 years

Assume Installation technicians @ $48 /hour/technician
Assume 16 hours per well for pump installation

26 pumps at	$788 each =	$20,488	
16 hrs/well at	$48 /hr =	$763	per well
26 wells at	$763 /well =	$19,838	installation

Total O&M Without Treatment System	**$146,388**
O & M with 5 year Replacement	**$186,714**
Total O&M Without Treatment System	**$64,204**
O & M with 5 year Replacement	**$104,530**

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$1,524**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 5 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110 /sample
Total (including 15% CLP) =	$127 /sample event

2. Labor (for Groundwater Well Sampling) **$1,920**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$625**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 5 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$9,429**

PRESENT WORTH CALCULATIONS

Plume J - Perimeter, In-Situ Treatment - with 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$1,693,000	$0	$0	1.0000	$1,693,000	$1,693,000
1	$0	$146,388	$9,429	0.9302	$155,817	$144,946
2	$0	$146,388	$9,429	0.8653	$155,817	$134,833
3	$0	$146,388	$9,429	0.8050	$155,817	$125,426
4	$0	$146,388	$9,429	0.7488	$155,817	$116,676
5	$0	$146,388	$9,429	0.6966	$155,817	$108,535
6	$0	$0	$9,429	0.6480	$9,429	$6,110
7	$0	$0	$9,429	0.6028	$9,429	$5,683
8	$0	$0	$0	0.5607	$0	$0
9	$0	$0	$0	0.5216	$0	$0
10	$0	$0	$0	0.4852	$0	$0
	$1,693,000	**$731,939**	**$66,003**			**$2,335,210**

Plume J - Perimeter, In-Situ Treatment ***$2,300,000***

PRESENT WORTH CALCULATIONS

Plume J - Perimeter, In-Situ Treatment - without 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$1,150,079	$0	$0	1.0000	$1,150,079	$1,150,079
1	$0	$64,204	$9,429	0.9302	$73,633	$68,496
2	$0	$64,204	$9,429	0.8653	$73,633	$63,717
3	$0	$64,204	$9,429	0.8050	$73,633	$59,272
4	$0	$64,204	$9,429	0.7488	$73,633	$55,136
5	$0	$64,204	$9,429	0.6966	$73,633	$51,290
6	$0	$0	$9,429	0.6480	$9,429	$6,110
7	$0	$0	$9,429	0.6028	$9,429	$5,683
8	$0	$0	$0	0.5607	$0	$0
9	$0	$0	$0	0.5216	$0	$0
10	$0	$0	$0	0.4852	$0	$0
	$1,150,079	**$321,019**	**$66,003**			**$1,459,782**

Plume J - Perimeter, In-Situ Treatment ***$1,500,000***

CAPITAL COSTS

1. Extraction Well Installation **$230,309**

A. Drilling $156,000

Assume Drilling costs at $150 per linear foot
Assume 26 wells at an average depth of 40 ft
Total 26 wells 1,040 linear feet

B. Pump Installation $40,326

Assume Installation technicians @ $48 /hour/technician
Assume 16 hours per well for pump installation

26 pumps at	$788	each =	$20,488	
16 hrs/well at	$48	/hr =	$763	per well
26 wells at	$763	/well =	$19,838	installation

C. Fencing (assume each well enclosed by 20 ft by 20 ft fence with one 12 ft gate) $33,983

68 linear feet of fence per well at	$10.28	/lf =	$699
1 12 ft gates per well at	$608	ea =	$608
		Subtotal =	$1,307

26 wells at $1,307 /well = $33,983

2. Extraction Pipe Installation (from extraction point to header) **$108,413**

A. HDPE Pipe $14,813

Pipe I.D., Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
2	1,920	96	$4.64	$1.37	$12,127
4	980	49	$0.00	$2.61	$2,686
			Subtotal		$14,813

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

B. Electrical and Instrumentation $93,600

Assume $3,000 per pump station to install cable, conduit, and handholes
26 wells at $3,000 per station $78,000

Assume $600 per pump station to install valves and flow elements
26 wells at $600 per station $15,600

3. Treatment System (100 gpm UV/OX) **$415,750**

A. Treatment System $415,750

Based on a ratio of flow rates relative to the cost of a 400 GPM system
System flow = 100 gpm
Cost of 400 gpm system = $1,663,000
Cost of the 100 gpm system = $415,750

TOTAL CAPITAL COSTS

Without Treatment system		With Treatment system	
Subtotal (ST)	**$338,722**	Subtotal (ST)	**$754,000**
Overhead and Profit @ 15.5%	**$53,000**	Overhead and Profit @ 15.5%	**$117,000**
Mob/Bond/Insur @ 5% of ST	**$17,000**	Mob/Bond/Insur @ 5% of ST	**$38,000**
Contingency @ 10% of ST	**$34,000**	Contingency @ 10% of ST	**$75,000**
Total	**$442,722**	Total	**$984,000**

O & M COSTS

1. Electrical Costs **$13,887**

Extraction System:

Assume	25.5	HP pump (37 GPM system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation **$82,184**

A. Labor and Maintenance $77,528

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	100 gpm	
Cost of	400 gpm system =	$310,111
Cost of the	100 gpm system =	$77,528

B. Treatment System Influent and Effluent Water Monitoring $4,656

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	100 gpm	
Cost of	400 gpm system =	$18,624
Cost of the	100 gpm system =	$4,656

3. Extraction Trench Pump Replacement **$21,251**

Assume extraction pumps will require replacement every 5 years

Assume Installation technicians @			$48	/hour/technician
Assume	16	hours per well for pump installation		
26 pumps at	$788	each =	$20,488	
16 hrs/pump at	$48	/hr =	$763	per pump

Total O&M Without Treatment System	**$96,071**
O & M with 5 year Replacement	**$117,322**
Total O&M Without Treatment System	**$13,887**
O & M with 5 year Replacement	**$35,138**

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$1,524**

Plume J - Perimeter, Exsitu

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 5 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$1,920**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$625**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 5 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$9,429**

PRESENT WORTH CALCULATIONS

Plume J - Perimeter, Exsitu - with 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$984,000	$0	$0	1.0000	$984,000	$984,000
1	$0	$96,071	$9,429	0.9302	$105,500	$98,139
2	$0	$96,071	$9,429	0.8653	$105,500	$91,292
3	$0	$96,071	$9,429	0.8050	$105,500	$84,923
4	$0	$96,071	$9,429	0.7488	$105,500	$78,998
5	$0	$96,071	$9,429	0.6966	$105,500	$73,487
6	$0	$0	$9,429	0.6480	$9,429	$6,110
7	$0	$0	$9,429	0.6028	$9,429	$5,683
8	$0	$0	$0	0.5607	$0	$0
9	$0	$0	$0	0.5216	$0	$0
10	$0	$0	$0	0.4852	$0	$0
	$984,000	**$480,353**	**$66,003**			**$1,422,632**

Plume J - Perimeter, Exsitu ***$1,400,000***

PRESENT WORTH CALCULATIONS

Plume J - Perimeter, Exsitu - without 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$442,722	$0	$0	1.0000	$442,722	$442,722
1	$0	$13,887	$9,429	0.9302	$23,316	$21,689
2	$0	$13,887	$9,429	0.8653	$23,316	$20,176
3	$0	$13,887	$9,429	0.8050	$23,316	$18,768
4	$0	$13,887	$9,429	0.7488	$23,316	$17,459
5	$0	$13,887	$9,429	0.6966	$23,316	$16,241
6	$0	$0	$9,429	0.6480	$9,429	$6,110
7	$0	$0	$9,429	0.6028	$9,429	$5,683
8	$0	$0	$0	0.5607	$0	$0
9	$0	$0	$0	0.5216	$0	$0
10	$0	$0	$0	0.4852	$0	$0
	$442,722	**$69,434**	**$66,003**			**$548,848**

Plume J - Perimeter, Exsitu ***$500,000***

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$1,524**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 5 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$1,920**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$625**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 5 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$9,429**

PRESENT WORTH CALCULATIONS

ANNUAL DISCOUNT RATE = 7.5%

YEAR	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$0	1.0000	$0	$0
1	$9,429	0.9302	$9,429	$8,771
2	$9,429	0.8653	$9,429	$8,159
3	$9,429	0.8050	$9,429	$7,590
4	$9,429	0.7488	$9,429	$7,060
5	$9,429	0.6966	$9,429	$6,568
6	$9,429	0.6480	$9,429	$6,110
7	$9,429	0.6028	$9,429	$5,683
8	$0	0.5607	$0	$0
9	$0	0.5216	$0	$0
10	$0	0.4852	$0	$0
11	$0	0.4513	$0	$0
12	$0	0.4199	$0	$0
13	$0	0.3906	$0	$0
14	$0	0.3633	$0	$0
15	$0	0.3380	$0	$0
16	$0	0.3144	$0	$0
17	$0	0.2925	$0	$0
18	$0	0.2720	$0	$0
19	$0	0.2531	$0	$0
20	$0	0.2354	$0	$0
21	$0	0.2190	$0	$0
22	$0	0.2037	$0	$0
23	$0	0.1895	$0	$0
24	$0	0.1763	$0	$0
25	$0	0.1640	$0	$0
26	$0	0.1525	$0	$0
27	$0	0.1419	$0	$0
28	$0	0.1320	$0	$0
29	$0	0.1228	$0	$0
30	$0	0.1142	$0	$0
	$66,003			**$49,942**

Plume J - Base Perimeter, Natural Attenuation ***$50,000***

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$3,048**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 10 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$3,840**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$1,250**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 10 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

1. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$13,498**

PRESENT WORTH CALCULATIONS

ANNUAL DISCOUNT RATE = 7.5%

YEAR	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$0	1.0000	$0	$0
1	$13,498	0.9302	$13,498	$12,556
2	$13,498	0.8653	$13,498	$11,680
3	$13,498	0.8050	$13,498	$10,865
4	$13,498	0.7488	$13,498	$10,107
5	$13,498	0.6966	$13,498	$9,402
6	$13,498	0.6480	$13,498	$8,746
7	$13,498	0.6028	$13,498	$8,136
8	$13,498	0.5607	$13,498	$7,568
9	$13,498	0.5216	$13,498	$7,040
10	$13,498	0.4852	$13,498	$6,549
	$134,980			**$92,651**

Plume K - Source Area, Natural Attenuation ***$90,000***

CAPITAL COSTS

1. Bioremediation Extraction Well Installation **$53,148**

A. Drilling $36,000

Assume Drilling costs at			$150	per linear foot	
Assume	6	wells at an average depth of		40	ft
Total	6	wells		240	linear feet

B. Pump Installation $9,306

Assume Installation technicians @			$48	/hour/technician	
Assume	16	hours per well for pump installation			
6 pumps at		$788	each =	$4,728	
16 hrs/well at		$48	/hr =	$763	per well
6 wells at		$763	/well =	$4,578	installation

C. Fencing (assume each well enclosed by 20 ft by 20 ft fence with one 12 ft gate) $7,842

68 linear feet of fence per well at	$10.28	/lf =	$699
1 12 ft gates per well at	$608	ea =	$608
		Subtotal =	$1,307

6 wells at	$1,307	/well =	$7,842	

2. Bioremediation Injection Well Installation **$116,913**

A. Drilling $96,000

Assume Drilling costs at			$150	per linear foot	
Assume	16	wells at an average depth of		40	ft
Total	16	wells		640	linear feet

B. Fencing (assume each well enclosed by 20 ft by 20 ft fence with one 12 ft gate) $20,913

68 linear feet of fence per well at	$10.28	/lf =	$699
1 12 ft gates per well at	$608	ea =	$608
		Subtotal =	$1,307

16 wells at	$1,307	/well =	$20,913	

4. Pipe Installation (from extraction & injection point to header) **$69,096**

A. HDPE Pipe $37,896

Pipe I.D., Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
Ext 2"	2,600	130	$4.64	$1.37	$16,422
Rtn 2"	3,400	170	$4.64	$1.37	$21,474
			Subtotal		$37,896

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

B. Electrical and Instrumentation $31,200

Plume K - Source Area, In-Situ

Assume	$3,000	per well to install cable, conduit, and handholes		
6 wells at	$3,000	per well =	$18,000	
Assume	$600	per well to install valves and flow elements		
22 wells at	$600	per well =	$13,200	

5. Treatment System (Bioremediation) **$99,069**

A. Treatment/Storage/Office Building $18,180

Assume a 20 ft x 20 ft building to house the each bioremediation treatment system

Concrete Foundation	15 CY (20ft x 20ft x 1 ft thick)			
Excavation	15 CY at	$3.25 /CY =	$49	
Compaction	15 CY at	$2.43 /CY =	$36	
Placement	15 CY at	$139.68 /CY =	$2,095	
Pre-Engineered Structure	400 square ft			
Including Building, Insulation, HVAC unit, Electrical, and Lighting.				
Assume	$40.00 /square ft =	$16,000		

B. Power to site $28,446

	Materials	Installation	Subtotal
Oil Filled Pad Mounted 112.5 KVA Transformer	$14,069	$426	$14,495
Watthour-meter and current transformers	$1,500	$500	$2,000
600A Main Circuit, breaker distribution	$10,451	$1,500	$11,951

C. In Situ Bioremediation Equipment $46,785

2,000 gallon H20 holding tank			$1,570
27.5 gpm pump			$1,295
1,000 gallon Methanol holding tank			$996
Metering pump			$1,627
Skid, tank penetrations, and delivery			$3,500
Braided Hose			$187
Cost of PLC			$5,942
Installation of PLC			$1,188.40
Programming of PLC			
(assume one engineer and one technician for 6 weeks per system)			
$54 /hr for	6 weeks =		$12,960
$48 /hr for	6 weeks =		$11,520
Flow measuring and control devices			$6,000
Assume	$5,000 for all valves and flow devices		
Labor	$1,000 (assumed at 20% of capital)		

D. Fencing $5,657

Assume each In-Situ Bioremediation system enclosed by 60 bt by 60 ft fence with two 12 ft gate

432 linear feet of fence at	$10.28 /lf =	$4,441	
2 12 ft gates at	$608 ea =	$1,216	

6. Treatment System (80 gpm UV/OX) **$332,600**

Based on a ratio of flow rates relative to the cost of a 400 GPM system $332,600

System flow =	80 gpm	
Cost of	400 gpm system =	$1,663,000
Cost of the	80 gpm system =	$332,600

7. Testing **$12,240**

Assume 4 technicians and 2 engineers for 3 weeks to test the system

4 Technicians at	$48 /hr for	3 weeks =	$5,760	
2 Engineers at	$54 /hr for	3 weeks =	$6,480	

8. Implementation Costs **$129,672**

Assume Implementation costs at 37% of Capital Costs
Includes Permitting and legal, Services During Construction, Health and Safety,
Report preparation, and engineering design costs.

TOTAL CAPITAL COSTS

Without Treatment System		With Treatment System	
Subtotal (ST)	**$480,138**	Subtotal (ST)	**$813,000**
Overhead and Profit @ 15.5%	**$74,000**	Overhead and Profit @ 15.5%	**$126,000**
Mob/Bond/Insur @ 5% of ST	**$24,000**	Mob/Bond/Insur @ 5% of ST	**$41,000**
Contingency @ 10% of ST	**$48,000**	Contingency @ 10% of ST	**$81,000**
Total	**$626,138**	Total	**$1,061,000**

O & M COSTS

1. Electrical Costs **$2,995**

Extraction System:

Assume	5.5	HP pump (Bioremediation system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation **$118,787**

A. Labor and Maintenance $62,022

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	80 gpm	
Cost of	400 gpm system =	$310,111
Cost of the	80 gpm system =	$62,022

B. Treatment System Influent and Effluent Water Monitoring $3,725

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	80 gpm	
Cost of	400 gpm system =	$18,624
Cost of the	80 gpm system =	$3,725

C. Insitu Bio System Operation $53,040

Assume 1 technician and 1 engineer quarter time to operate the system

1 Technician at	$48 /hr for	13 weeks =	$24,960
1 Engineer at	$54 /hr for	13 weeks =	$28,080

3. Extraction Well Pump Replacement **$9,306**

Assume extraction pumps will require replacement every 5 years

Assume Installation technicians @ $48 /hour/technician
Assume 16 hours per well for pump installation

6 pumps at	$788	each =	$4,728	
16 hrs/well at	$48	/hr =	$763	per well
6 wells at	$763	/well =	$4,578	installation

Total O&M Without Treatment System	**$121,782**
O & M with 5 year Replacement	**$131,088**
Total O&M Without Treatment System	**$56,035**
O & M with 5 year Replacement	**$65,341**

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$3,048**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)
Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 10 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$3,840**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$1,250**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 10 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$13,498**

PRESENT WORTH CALCULATIONS

Plume K - Source Area, In-Situ Treatment - with 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$1,061,000	$0	$0	1.0000	$1,061,000	$1,061,000
1	$0	$121,782	$13,498	0.9302	$135,280	$125,842
2	$0	$121,782	$13,498	0.8653	$135,280	$117,062
3	$0	$121,782	$13,498	0.8050	$135,280	$108,895
4	$0	$121,782	$13,498	0.7488	$135,280	$101,298
5	$0	$131,088	$13,498	0.6966	$144,586	$100,713
6	$0	$121,782	$13,498	0.6480	$135,280	$87,656
7	$0	$121,782	$13,498	0.6028	$135,280	$81,541
8	$0	$121,782	$13,498	0.5607	$135,280	$75,852
9	$0	$121,782	$13,498	0.5216	$135,280	$70,560
10	$0	$121,782	$13,498	0.4852	$135,280	$65,637
	$1,061,000	**$1,227,129**	**$134,980**			**$1,996,057**

Plume K - Source Area, In-Situ Treatment ***$2,000,000***

PRESENT WORTH CALCULATIONS

Plume K - Source Area, In-Situ Treatment - without 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$626,138	$0	$0	1.0000	$626,138	$626,138
1	$0	$56,035	$13,498	0.9302	$69,533	$64,682
2	$0	$56,035	$13,498	0.8653	$69,533	$60,169
3	$0	$56,035	$13,498	0.8050	$69,533	$55,971
4	$0	$56,035	$13,498	0.7488	$69,533	$52,066
5	$0	$65,341	$13,498	0.6966	$78,839	$54,916
6	$0	$56,035	$13,498	0.6480	$69,533	$45,055
7	$0	$56,035	$13,498	0.6028	$69,533	$41,911
8	$0	$56,035	$13,498	0.5607	$69,533	$38,987
9	$0	$56,035	$13,498	0.5216	$69,533	$36,267
10	$0	$56,035	$13,498	0.4852	$69,533	$33,737
	$626,138	**$569,658**	**$134,980**			**$1,109,902**

Plume K - Source Area, In-Situ Treatment ***$1,100,000***

CAPITAL COSTS

1. Extraction Well Installation **$17,716**

A. Drilling $12,000

Assume Drilling costs at $150 per linear foot
Assume 2 wells at an average depth of 40 ft
Total 2 wells 80 linear feet

B. Pump Installation $3,102

Assume Installation technicians @ $48 /hour/technician
Assume 16 hours per well for pump installation

2 pumps at	$788	each =	$1,576	
16 hrs/well at	$48	/hr =	$763	per well
2 wells at	$763	/well =	$1,526	installation

C. Fencing (assume each well enclosed by 20 ft by 20 ft fence with one 12 ft gate) $2,614

68 linear feet of fence per well at	$10.28	/lf =	$699
1 12 ft gates per well at	$608	ea =	$608
		Subtotal =	$1,307

2 wells at $1,307 /well = $2,614

2. Extraction Pipe Installation (from extraction point to header) **$22,358**

A. HDPE Pipe $15,158

Pipe I.D., Diameter in.	Pipe Length feet	Pipe Fittings feet (a)	Unit Cost Excavation $/lf	Unit Cost Pipe Installation (b) $/lf	Subtotal
2	2,400	120	$4.64	$1.37	$15,158
			Subtotal		$15,158

(a) Assume 5% of pipe length attributed to fittings
(b) Includes materials and labor

B. Electrical and Instrumentation $7,200

Assume $3,000 per pump station to install cable, conduit, and handholes
2 wells at $3,000 per station $6,000

Assume $600 per pump station to install valves and flow elements
2 wells at $600 per station $1,200

3. Treatment System (30 gpm UV/OX) **$124,725**

A. Treatment System $124,725

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	30	gpm	
Cost of	400	gpm system =	$1,663,000
Cost of the	30	gpm system =	$124,725

Plume K - Source Area, Exsitu

TOTAL CAPITAL COSTS

Without Treatment System		With Treatment System	
Subtotal (ST)	**$40,074**	Subtotal (ST)	**$165,000**
Overhead and Profit @ 15.5%	**$6,000**	Overhead and Profit @ 15.5%	**$26,000**
Mob/Bond/Insur @ 5% of ST	**$2,000**	Mob/Bond/Insur @ 5% of ST	**$8,000**
Contingency @ 10% of ST	**$4,000**	Contingency @ 10% of ST	**$17,000**
Total	**$52,074**	Total	**$216,000**

O & M COSTS

1. Electrical Costs **$4,084**

Extraction System:

Assume	7.5	HP pump (12 GPM system)
Assume	60%	Pump Efficiency
Assume	8760	System run time (hours/year)
Assume	$0.050	per kilowatt hour

2. Treatment System Operation **$24,655**

A. Labor and Maintenance $23,258

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	30	gpm	
Cost of	400	gpm system =	$310,111
Cost of the	30	gpm system =	$23,258

B. Treatment System Influent and Effluent Water Monitoring $1,397

Based on a ratio of flow rates relative to the cost of a 400 GPM system

System flow =	30	gpm	
Cost of	400	gpm system =	$18,624
Cost of the	30	gpm system =	$1,397

3. Extraction Trench Pump Replacement **$2,339**

Assume extraction pumps will require replacement every 5 years

Assume Installation technicians @			$48	/hour/technician
Assume	16	hours per well for pump installation		
2 pumps at	$788	each =	$1,576	
16 hrs/pump at	$48	/hr =	$763	per pump

Total O&M With Treatment System	**$28,740**
O & M with 5 year Replacement	**$31,079**
Total O&M Without Treatment System	**$4,084**
O & M with 5 year Replacement	**$6,423**

GROUNDWATER MONITORING COSTS

1. Groundwater Monitoring and Extraction Well Sample Analysis **$3,048**

Assume one sample semiannually until system shutdown
Assume 1.2 samples/well each sampling event (includes QA samples)

Plume K - Source Area, Exsitu

Assume QA samples include 1 field Blank and 1 Duplicate for every 10 samples
Assume 10 existing groundwater monitoring wells for sampling
Assume each sampling event includes:

VOCs (EPA 601/SW 8010)	$110	/sample
Total (including 15% CLP) =	$127	/sample event

2. Labor (for Groundwater Well Sampling) **$3,840**

Assume rate for 2 sampling technicians @ $48 /hour/technician
Assume 2 hours/well/sampling event for sampling, shipping, etc.
Assume 2 sample events/year

3. Rental of Equipment (for Groundwater Well Sampling) **$1,250**

Assume rental of sampling equipment, shipping, etc. @ $250/day
Assume 10 existing groundwater monitoring wells
Assume 2 hours per well for sampling
Assume 2 sample events/year

4. Labor (for Data Analysis and Validation of Groundwater Data) **$5,360**

Assume 1 man-week per sampling event
Assume chargeout rate for 1 - Validation Chemist @ $67/hour
Assume 2 sample events/year

TOTAL MONITORING COSTS **$13,498**

PRESENT WORTH CALCULATIONS

Plume K - Source Area, Exsitu - with 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$216,000	$0	$0	1.0000	$216,000	$216,000
1	$0	$28,740	$13,498	0.9302	$42,238	$39,291
2	$0	$28,740	$13,498	0.8653	$42,238	$36,549
3	$0	$28,740	$13,498	0.8050	$42,238	$34,000
4	$0	$28,740	$13,498	0.7488	$42,238	$31,627
5	$0	$31,079	$13,498	0.6966	$44,577	$31,050
6	$0	$28,740	$13,498	0.6480	$42,238	$27,368
7	$0	$28,740	$13,498	0.6028	$42,238	$25,459
8	$0	$28,740	$13,498	0.5607	$42,238	$23,683
9	$0	$28,740	$13,498	0.5216	$42,238	$22,030
10	$0	$28,740	$13,498	0.4852	$42,238	$20,493
	$216,000	**$289,734**	**$134,980**			**$507,551**

Plume K - Source Area, Exsitu ***$500,000***

PRESENT WORTH CALCULATIONS

Plume K - Source Area, Exsitu - without 400 gpm Treatment System

ANNUAL DISCOUNT RATE = 7.5%

YEAR	CAPITAL COST	O&M COST	MONITORING COST	DISCOUNT FACTOR	ANNUAL EXPENDITURE	PRESENT WORTH
0	$52,074	$0	$0	1.0000	$52,074	$52,074
1	$0	$4,084	$13,498	0.9302	$17,582	$16,356
2	$0	$4,084	$13,498	0.8653	$17,582	$15,215
3	$0	$4,084	$13,498	0.8050	$17,582	$14,153
4	$0	$4,084	$13,498	0.7488	$17,582	$13,166
5	$0	$6,423	$13,498	0.6966	$19,921	$13,876
6	$0	$4,084	$13,498	0.6480	$17,582	$11,393
7	$0	$4,084	$13,498	0.6028	$17,582	$10,598
8	$0	$4,084	$13,498	0.5607	$17,582	$9,858
9	$0	$4,084	$13,498	0.5216	$17,582	$9,171
10	$0	$4,084	$13,498	0.4852	$17,582	$8,531
	$52,074	**$43,183**	**$134,980**			**$174,390**

Plume K - Source Area, Exsitu ***$200,000***